Sudan University of Science and Technology

College of Graduate Studies

Screening Some Grain Sorghum (*Sorghum bicolor* L. Moench) Genotypes for Grain Yield and Plant Tolerance Against Stem Borers *Chilopartellus* (Swinhoe) and*Sesamiacretica* (Led.)

مسح لبعض الطرز االوراثية لمحصول الذرة الرفيعة لانتاجية الحبوب وتحمل النبات للاصابة بثاقبات الساق (دودة الذرة المنقطة ودودة الذرة غير المنقطة)

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A Thesis Submitted to the SudanUniversity of Science and Technology in Fulfillment of the Requirements for the Degree of Ph.D. in Plant Protection (Entomology)

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September 2018

DEDICATION

This work is dedicated
To my mother
To my father
To my aunt (bakhita)
To my husband

Mawahib

ACKNOWLEDGEMENTS

Praise be to Allah .The Al mighty , who gave me health , strength and patience to complete this study successfully and peace be upon Prophet**MOHAMD**.

Great appreciation is due to my main supervisor Dr. **Seif Eldin Mohammed Khair** for his unanimous support, guidance and encouragements for the first steps of this research up to its end. I would like to express particular thanks and real gratitude and deep appreciation to my Co – supervisor Dr. **Atif El Sadig Idris** for his patience, help, time, and real support on this study until it was completed .Special thanks are extended to Dr.**Maarouf Ibrahim** and Dr. **Mohammed** (ARC) who provided me withmaterials used in this study. Also,I wish to express my thanks to Dr.**Ashwag** and Mr**. Mubarak Zaroog** for uncountable support and assistance and valuable advices. Thank are due to Mr. **Salah Mahgoob** and the staff of the departments of Agronomy laboratory, College of Agricultural Studies Sudan University of Science and Technology for their valuable help and advices.

I also wish to extend my thanks to all members of Shambat library.

No words can express my feeling towards my grand family,my affectionate mother (Aisha) my father (Mubarak),lovely mother (Bakhita), brothers (Mamoon, Mejdee, Mutaz, Khalied) ,sisters (Majda, Ebtihaj) and my husband.

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ABSTRACT

In Sudan, Sorghum (*Sorghum bicolor* L. Moench) is affected by mainly two lepidopteron stem borers, *Chilopartellus* and*Sesamiacretica* causing considerable decrease in the yield. A survey was conducted to assess the incidence and distribution of stem borers in Summer sowed sorghum in Khartoum state and to evaluate the status of stem borers infestation on sorghum growing in Khartoum State in eight locations (Al Khadroo, El fakeiHashim, Shambat, Seleet Scheme (north Khartoum) Soba (east Khartoum) El Gezira Islang (north Omdurman), Toti Island (central Khartoum) and Tiba (south Khartoum). The results showed that, the sorghum crop in the study sites was variably infested by both stem borers. The highest infestation of all sites surveyed was recorded in Shambat (60.34%) and the lowest infestation was recorded in Soba (31.7%). There was a significant difference between the number of *Chilopartellus* and *Sesamiacretica* in the infested areas. The highest infestation was recorded in Shambat(*Chilopartellus*65.25% while that *Sesamiacretica* was 59.99%). The lowest infestation by both agents was found in Soba (*Chilopartellus* as 33.26%, while that *Sesamiacretica* was 30.37%).

Two field experiments were conducted under irrigation at the Experimental Farm of the College of Agricultural Studies, Sudan University of Science and Technology, Shambat, Sudan for two cropping seasons (Autumn and Winter) during 2016-17. The experiment was arranged in Randomized Complete Block Design (RCBD) with three replications, to screen the relative resistance/susceptibility of twenty-two genotypes of sorghum against stem borers (*Chilopartellus, Sesamiacretica*), and to assess for yield and yield components, assess the impact of genetic variability

among grain sorghum genotypes, estimates the phenotypic correlation between different characters and to assess the heritable component of the total phenotypic variability using the parameters genetic coefficient of variation and heritability.

The plants were subjected to natural infestation by stem borers. Four resistance expressing traits were recorded, i.e. percentage of infested plants, percentage of plants with dead hearts, tunnels length and intensity of damage. The results showed that in Autumn, the maximum level of leave damage was found in F-6 (61.59%), and minimumwas found in G.1.1.4(12.18%), while in Winter, the maximum level of leave damage was found in F-6 (59.15%) and minimum was found in G.1.1.4(15.12%). The percentage of plants with dead hearts formations was higher in more susceptible genotypes than least susceptible genotypes. Results showed that, G.1.1.4 was found to be the most resistant to all studied types of damage The Maximum occurrences of dead hearts were recorded in genotypes F-6(4.99%, 4.21%) in Autumn and Winter respectively. The higher and lower Value of tunnels length ranged between F-6 (5.32cm) to Tabat (2.38) in Autumn, and F-6(5.38cm) to G.1.1.16 (2.67cm) in Winter season.

The following growth and yield traits were measured: plant height, stem diameter, number of leaves /plant, leaf area, days to 50% flowering, days to physiological maturity, panicle length, panicle width, panicle exertion,1000 seeds weight and grain yield ton/ha. The results showed that there were significant differences among the 22 sorghum genotypes for some growth yield and stem borer's infestation in both seasons. Genotypes (F- 6) scored the highest grain yields (1.34t/ha), (1.28 t/ha) in Autumn and Winter respectively, in spite of high leave damage 61.59%, 59.15% and high tunnels length 5.32cm, 5.38cm. This result illustrates the ability of the

genotypes to produce high yield coupled with their tolerance to stem borer infestation. Genotype F-6 could be of advantage for any future sorghum breeding program. All genotypes gave higher yields in Autumn than in Winter. This can attributed to the favorable environmental conditions during the rainy season coupled by the lighter infestation of the stem borers.

Genotypes F-5, F-15 gave highest value 197cm, 195 cm in Autumn and Winter respectively. The earliest flowering genotype was Arfagadmk (64.3days and 59.6days) in both Autumn and Winter seasonrespectively. For 1000-grain weight genotype G.1.1.4 (46.1g and 45.0g) in Autumn and Winter respectively. The phenotypic and genotypic variances, phenotypic (PCV) and genotypic (GCV) coefficient of variation, heritability (h2), phenotypic and genotypic correlation between different characters were calculated. There was a wide phenotypic variation among the genotypes in most of the characters studied. The genotypic component of the phenotypic variance was consistently higher than the heritability broad sense estimates that ranged from (95% - 41%).

High heritability was reflected in this study among the following growth characters: plant height (0.95-0.88), days to maturity (0.76-0.83), days to 50% flowering (0.73-0.84) and leaf area (0.67-0.92) for both seasons. Genotypic coefficient of variation (GCV) was maximumin Leaf area (2313.70 and 4665.9) plant height (999.63 and 1162.66) for both seasons and it was not different than phenotypic coefficient of variation (PCV). It showed maximum value in leaf area (3444.38 and 5045.60) and plant height (1047.93 and 1327.46) for both seasons.This result indicated that these traits were affected by environmental fluctuations. The high values of (GCV) and (PCV) suggest the possibility of utilizing environmental effects through direct selection for these traits.

Estimates of phenotypic correlations among different characters in the two seasons were variable from one season to another. Grain yield ton/ha had strong positive phenotypic correlation with some of the morphological characteristics and the susceptibility of the plant to stem borers.This indicates that the strong inherent associations between different traits are different under the different environments and hence the phenotypic correlations are dependent on environmental conditions.

الملخص

الذرة الرفيعة في السودان تتعرض بشكل اساسي لنوعين من ثاقبات الساق (دودة الذرة المنقطة ودودة الذرة غير المنقطة) مسببه نقصان مقدر في الانتاجية. تم اجراء مسح لتقييم مدي انتشار وتوزيع آفة ثاقبات الساق في الذرة الرفيعة في ولاية الخرطوم ، وتقييم حالة الاصابة بثاقبات الساق علي نمو الذرة الرفيعة في ثمانية مواقع بولاية الخرطوم (الكدرو- الفكي هاشم – شمبات - مشروع السليت – سوبا – الجزيرة اسلانج – جزيرة توتي – طيبة). اظهرت النتائج ان محصول الذرة الرفيعة في جميع المواقع التي شملتها الدراسة كان مصاب بدرجات متفاوتة بكلا النوعين من ثاقبات الساق , اعلي نسبة اصابة في جميع المواقع التي شملها المسح سجلت في شمبات(60.34%) وكانت اقل اصابة سجلت في سوبا (31.7%) .وكان هناك فرق معنوي بين اعداد الاصابة بدودة الذرة المنقطة ودودة الذرة غيرالمنقطة في مناطق الاصابة. أعلي اصابة بدودة الذرة المنقطة سجلت في شمبات بنسبة 65.25% بينما كانت اعلي اصابة بدودة الذرة غيرالمنقطة بنسبة 59,99% .اما أقل حالات الاصابة فقد تم العثور عليها في سوبا بنسبة 33,26% لدودة الذرة المنقطة .في حين كانت بنسبة 30,37% بدودة الذرة غيرالمنقطة.

أجريت تجربتين حقليتين بالري في المزرعة التجريبية بكلية الدراسات الزراعية – جامعة السودان للعلوم والتكنولوجيا في (شمبات) ولاية الخرطوم-السودان في العروة الصيفية والشتوية في موسمي 16-2017 . حيث تم استخدام تصميم القطاعات العشوائية الكاملة بثلاث مكررات لفحص المقاومة النسبية والقابلية للاصابة لـــ 22 من الانماط الوراثية من الذرة الرفيعة لثاقبات الساق ،وتقييم مكونات المحصول والعائد، وتقييم التباين الوراثي بين التراكيب الوراثية لحبوب الذرة الرفيعة, ولتقدير الارتباط المظهري بين الصفات المختلفة, ولتقييم المكون الوراثي للتغيير المظهري الكلي باستخدام المعلمات المعامل الجيني للتباين والتوريث.

تركتالنباتات للاصابة الطبيعية من قبل ثاقبات الساق، باستخدام اربعة صفات للتعبير عن المقاومة التي سجلت: وهي النسبة المئوية للنباتات المصابة والنسبة المئوية للنباتات ذات القلوب الميتة وطول الانفاق في الساق وكثافة الضرر . اظهرت النتائج في الخريف الحد الاقصي لمستوي ضرر الورقة للنمط(61.59%) F-6 وكان الحد الادني للنمط (12.18%)G.1.1.4 بينما في فصل الشتاء تم العثور علي الحد الاقصي لمستوي ضرر الورقة للنمط(59.15%) F-6 وكان الحد الادني للنمط (15.12%)G.1.1.4 . كانت النسبة المئوية للنباتات ذات القلوب الميتة اعلي في الانماط الوراثية الاكثر حساسية من الانواع الوراثية الاقل حساسية. اوضحت النتائج ان النمط

الجيني G.1.1.4 اعطي اعلي مستوي مقاومة فيما يتعلق بجميع انواع الضرر التي تمت دراستها , سجل الطراز الوراثي F-6 (4.99 ,4.21 %) اعلي قيم لموت القلب في الخريف والشتاء علي التوالي , وتراوحت قيمة طول الانفاق في الساقالاعلي والادني بين (5.32 سم) F-6 إلى (2.38) طابت في الخريف ،و (5.38 سم)F-6 الي (2.67 سم) G.1.1.16 في فصل الشتاء.

تم قياس صفات النمو والانتاجية التالية : طول النبات , سمك الساق, عدد الاوراق/ النبات, مساحة سطح الورقة , عدد الايام لـــ 50% ازهار , عدد الايام للنضج , طول القندول ,وعرض القندول طول رقبة القندول , ووزن الالف بذرة والانتاجية بالطن للهكتار. اوضحت النتائج وجود فروقات معنوية عالية بين الـ 22طراز وراثي من الذرة الرفيعة في بعض صفات النمو والانتاجية والاصابة بثاقبات الساق في كلا الموسمين. وسجل الطراز الوراثي F-6 اعلي محصول للحبوب1.28طن/هكتار , 1.34 طن /هكتار في الخريف والشتاء علي التوالي علي الرغم من احرازه قيم عالية لتلف الاوراق61.59% ، 59.15%واعلي طول نفق في الساق 5.32 سم،5.38سم على التوالي. توضح هذه النتائج قدرة الطراز الجيني في الحصول علي انتاجية عالية متزامنة مع اصابتها بثاقبات الساق ولذلك يمكن ان يكون الطراز الجيني F-6 مفيد لاي برنامج تربية ذرة رفيعة في المستقبل. اعطت الطرز الوراثية مستوي انتاجية اعلي في الخريف مقارنة بالشتاء ويمكن ان يكون ذلك علي الارجح بسبب الظروف البيئية المؤاتية التي يعزي اليها موسم الامطار والاصابة الاخف من قبل ثاقبات الساق. الانماط الوراثية F-5, F-15 اعطت تفوقا في الطول(197سم), (195سم) في الخريف والشتاء علي التوالي بينما كان النمط الوراثي Arfagadmk مبكر في التزهير (64.3 يوم، 59.6 يوم)في الخريف والشتاء علي التوالي, اظهر النمط G.1.14 اعلي وزن للالف حبة (46.2 جرام و45.3 جرام) في الخريف والشتاء علي التوالي.

تم حساب التباينات المظهرية والوراثية ومعاملات التباينات المظهرية والوراثية, ودرجة (معامل) التوريث , والارتباط المظهري بين مختلف الصفات المدروسة. اظهرت النتائج تباينا كبير بين الطرز الوراثية في الصفات المورفولوجية التي تمت دراستها وقد كان المكون الوراثي من التباين المظهري اكبر باستمرار من المكون البيئي وانعكس هذا ايضا في قيم درجة التوريث العالية التي تراوحت بين (95%-41%) .

اظهرت صفات النمو درجة توريث (h^2) عالية مقارنة بصفات الانتاجية ., في طول النبات (h^2=0.95-0.88), ايام النضج (h^2=0.76-0.83) , وعدد ايام 50% ازهار (- h^2=0.73 0.84) , ومساحة سطح الورقة (h^2=0.67- 0.92) لكلاللموسمين,

درجة الاختلاف في الصفات الوراثية (GCV) سجلت اعلي في مساحة الورقة (4665,9-2313,70) وطول النبات (1162.66 – 999.63) للموسمين علي التوالي. اما درجة الاختلاف في الصفات المظهرية (PCV) فلا تختلف عن درجة الاختلاف في الصفات الوراثية (GCV) حيث نجدها سجلت اعلي درجاتلصفه مساحة سطح الورقة (3444.38 - 5045.60) وطول النبات(1047.93 – 1327.46) في كلاالموسمين علي التوالي. اشارت هذه النتيجة الي ان هذة السمات تأثرت بالتقلبات البيئية , تشير القيم العالية (PCV) و (GCV) الي امكانية الاستفادة من هذه التاثيرات المناخية والبئية من خلال الانتخاب المباشر لهذة الصفات.

كانت التقديرات للارتباطات المظهرية بين الصفات المختلفة في الموسمين متغيرة من موسم الي آخر , كان وزن محصول الحبوب طن/هكتار له ارتباط موجب وقوي مع بعض الصفات المورفولجية ومدي قابلية المحصول للاصابة بثاقبات الساق. وهذا يشير الي ان التلازمات القوية المتوارثة بمختلف الصفات تختلف باختلاف تأثير البيئة ومن ثم فأن الارتباطات المظهرية تعتمد علي الظروف البيئية.

CHAPTER ONE
INTRODUTION

Sorghum [*Sorghum bicolor* (L.) Moench] is one of the most important cereal crops grown worldwide. It ranks fifth after wheat, maize, rice and barley (Doggett, 1988; Belum,*et al.,* 2004; Markus and Gurling, 2006 and FAO, 2011). Sorghumoriginated in eastern Africa, (Sudan along with Ethiopia –Eretria areas) and now is cultivated widely in tropical and subtropical regions. It is the most important staple cereal crop for more than 500 million people in more than 30 countries worldwide (ICRISAT,2011). Sorghum produced worldwide is 64.20 million tons with a cultivated area of 41 million hectares. of this grain, about 26 million tons are produced in Africa. The four leading sorghum producers in Africa are Nigeria, Ethiopia, Burkina Faso and Niger. Sorghum grains is the staple human food in many part of Africa and Asia and is one of sorghum grains used for the production of alcoholic beverages, syrups and fuel(Duncan, 1996). In Sudan, Sorghum is the first food crop before wheat and pearl millet. It is fully utilized; the grains are used for making Kisra (Bread from fermented dough), thick porridge (Aseeda) and soft drink (Abreh). The stalks are used as building materials, fuel and animals feed (Taha, 1998; Elzeinand Elasha,2005). Sorghum grain has limited use for livestock. Its use is limited, however, because the starch and protein in sorghum are more difficult for animals to digest than starches and protein in corn. In Sudan, the area under irrigated sorghum is about 8% while 92% is rain - fed (Fadlelmula, 2009). In Sudan Sorghum is grown in an area ranging from 4.3 to 7.1 million t/ha with an average of 5.2 million t/ha (Elzein and Elamin, 2006). The national average grain yield is 600 kg/ha which is very low compared to the world average of production 1288 kg/ha (Abdalla, 1999 and Elzein, 2008). Recently, Sorghum with its essential components has become an important research subject in the tropics and subtropics. Insect pests are

considered as one of the major yield limiting factors of sorghum (Obilana *et al.*, 1982). In Sudan sorghum is attacked by different species of stem borer, which caues great losses in yield in the rain –fed and irrigated schemes. Strategies to reduce these losses have, in the past, relied heavily on the use of chemical pesticides without regard to the complexities of the ecosystem, particularly the population dynamics of the pest and its natural enemies, has been one of the basic shortcomings of this control strategy. Germplasm characterization refers to the observation, measurement and heritable plant traits in a collection. The resulting data allows the identification and classification of accessions, building a catalog of descriptors with embedded biological information that are essential to collection management or to direct use in agriculture. Today Germplasm characterization has been developed based mostly on morphological descriptors and molecular marker technology.

The spotted stem borer, *Chilo partellus* Swinhoe), has been reported as the most important stem borer of sorghum in Asia and Eastern and Southern parts of Africa (Pathak and Olela 1983; Harris, 1989).Grain losses of 56% and 88%are reorted due to spotted stem borer infested 20 and 10 days after emergence,respectively (Starks,1969; Seshu Reddy, 1985).The invasive stem borer, *Chilo partellus* Swinhoe), has proved to be highly competitive colonizer in many of the areas it has invaded in Eastern and Southern Africa. Often becoming the most injurious stem borer (Kfir, 1977; Seshu Reddy, 1983). Maes (1998) listed 21 economically important lepidopteran stem borers on cultivated grasses in Africa. While *Sesamia cretica* Ledrer, has proved to be highly competitive colonizer in Africa it was reported in Morocco, Egypt, Sudan, Somalia (Tams and Bowden,1953) and extreme northern Kenya (Nye,1960). Outside of Africa it occurs in South and West Mediterranean, Yemen, Crete, India, Sri – Lanka and Thailand (Tams and Bowden,1953). In the Sudan, the moth occurs in the drier, irrigated parts, especially in the Northern and Central Sudan (Schmutterer, 1969).

In Sudan *Chilo partellus* is predominant in central rain land, while *Sesemia cretica* in irrigated areas of northern Sudan. Symptoms of damage on leaves are usually used to distinguish between *Chilo spp* Damage which makes regular holes in transverse rows and *Sesemia sp.* Which make irregular holes distributed at random. The true parameter is dead-heart effect and stalks as a result of larvae mines (Schmutterer,1969; Hill, 1983). Damage symptoms of *Chilo partellus* in sorghum include leaf feeding, deadheart, exit holes, stem tunnels and chaffy grain in case of extensive stem tunneling and peduncle damage (Jose *et al.*, 2001; Kishore *et al.,* 2007 and Sally *et al.,* 2007). Stem borers reduce grain yield through leaf feeding, deadheart and stem damage (Karaya *et al.,* 2009 and Beyene *et al.,* 2011). Techniques to screen for resistance to stem borers have been described by several workers (Jotwani, 1978, Taneja and Leuschner1985). Yield losses due to stem –borers vary from region to region. It is estimated to range from 20 % to 80% depending on the infestation of the pest and the growth stage of the crop (Haile and Hofsvang,2002 quoting various sources). Siddig in an article in Kranz *et al.,* (1977) reported *Chilo partellus* as primary cause of grain losses in sorghum in the Sudan.

The increase of stem borer in the agricultural schemes the Sudan create a challenge that requires extensive research work to screen and select sorghum genotypes characterized with high resistance to stem borer in order to increase sorghum production. In Khartoum State no comprehensive studies have been conducted on stem borers. Therefore, the main objectives of this study are:

1. To assess the incidence and distribution of stem borers in Summer Sowed sorghum in Khartoum State (in Sudan).
2. To assess severity of damage caused by both stem borers(*Chilo partellus, Sesamia cretica*)
3. To determine relative resistance of different genotypes against stem borers.
4. To determine the genetic variability in different 22 genotypes of sorghum.

5. To determine the yield and yield-related agronomical traits in some stem borers resistant and susceptible sorghum genotypes.
6. To assess the heritable component of the total phenotypic variability using the parameters genetic coefficient of variation and heritability.
7. To estimate phenotypic correlation between different characters.

CHAPTER TWO
LITERATURE REVIEW

2.1 Origin and geographic distribution of sorghum

It is generally agreed that cultivated sorghum arose from the wild *Sorghumbicolor* subspecies averticilliflorum (Stead.) Piper (Doggett,1988). These wild forms were confined to Africa until recently, implying that domestication occurred in Africa. Both Doggett, (1965) and Mann *et al.,* (1983) argued that the greatest variability in the crop and wild sorghums is found in the north- east quadrant of Africa (north of the equator, east of latitude 250E) and this was probably the centre of th first domestication, approximately 5000 years ago. However, Harlan and De Wet (1972), using archaeological, palaeobotanical, anthropological and botanical evidence, suggested that domestication occurred at different times in an area extending from the Ethiopian border, west through Sudan and up to Lake Chad. Doggett, (1965) and Wall and Ross (1970) postulated that sorghum was domesticated in Ethiopia some 3000 or more years ago from the wild Sorghum species (*Sorghum arundinaceum*) by disruptive selection, and from there it spread to other parts of world. However, Evelyn (1951), on the basis of wide variability in cultivated and wild sorghum in Kordofan and Kassala States, considered the Sudan as the center of origin of the crop. In a study involving more than 10.000 accessions from the world sorghum collection at ICRISAT, Murty *et al.,* (1967) reported that the Sudan appears to have greater diversity than does Ethiopia. In contrast to one center of origin hypothesis, de Wet and Huckabay (1967) proposed a polyphyletic origin for Africa cultivated sorghums. They considered that sorghums of West Africa were developed from *S. arundinaceum* var . *arundinaceum,* those of North –eastern Africa from var. *aethiopocum*, and the Eastern – central Africa group from var. *verticilliflorum*. However, most evidence point to the north –east quadrant of

Africa, which includes Sudan, Ethiopia and Eritrea, as the center of origin of sorghum, where the greatest variability is found (Purseglove, 1975).

2.2 Economic importance of sorghum

Sorghum (*Sorghum bicolor* (L) Moench) is the fifth most important cereal crop after wheat, rice, maize and barley in the world (Markus and Gurgling, 2006; Sher, *et al.*,2014), However , it has a wide range of other applications that are being explored with worldwide interest in renewable resources. Taylor (2003) reviewed the importance of sorghum in Africa. In terms of tonnage, sorghum is Africa's second most important cereal. The crop is a staple to more than 500 million people in arid and semi-arid tropics in Africa and Asia (Charles *et al.*, 2006). In Africa, about 25 million tons of sorghum are produced per annum which translates to one-third of the world crop (FAOSTAT, 2008). In sub Saharan Africa, sorghum is primarily a crop of resource-for, small-scale farmers (Mace *et al.*, 2009). In East Africa, sorghum has recently become an important industrial crop for the manufacture of beer and its starch has potential in bio-energy production (Taylor, 2010). In Kenya, sorghum is ground into flour and mixed with other types of flour for baby food. Stalks are used for fuel, thatching huts and as animal feed (Siband,1985; Charles *et al.*, 2006).

Sorghum utilizes C4 photosynthetic pathway thus has greater efficiency of dry matter production relative to water use (Charles *et al.*, 2006). The crop also tolerates longer durations of water logging than maize (Dillon *et al.*, 2007). These unique characteristics make Sorghum an ideal crop in arid, semi arid and areas at risk of desertification. In the face of global warming and climate change, sorghum is a promising alternative for enhanced food and income security, compared to commodity staples such as maize that often fail due to drought. Sorghum improvement through breeding is essential to enhance the crop's potential in food and income security in sub Saharan Africa.

Sorghum is cultivated in East and Horn of Africa where rainfall is intermittent and characterized by short periods of high rainfall (Charles *et*

al.,2006). In East Africa, the crop grows well in a wide range of environments between 500 meters and 1700 meters above sea level with seasonal rainfall of 300mm and above. Sorghum is drought tolerant thus has become an alternative crop in several areas in Kenya like Eastern, Nyanza and Coast provinces where major staples like maize fail due to lack of enough rain (Taylor, 2010).

2.3 Uses of sorghum

Rooney and Waniska (2000) provide a tremendous overview of the uses of sorghum in food and industry. Worldwide, sorghum has been used for human food, animal feed, building material and fencing (House 1985, Doggett 1988). Traditionally, sorghum is used in unfermented and fermented breads, porridges, couscous, rice like products, snacks, and malted alcoholic and non-alcoholic beverages in many African and Asian countries. Sorghum can be used to produce foods that are gluten free and in this respect the potential for new food uses exists for both the US and Europe. Broomcorn is a classic example of industrial use of sorghum in Europe (Berenji and Kisgeci, 1996). In Sudan grain sorghum is the most important cereal crop and is considered the main food for more than 70% of the population. The stalks are used as building material and the straw is used as animal feed or as a source of fuel. Sorghum is undoubtedly the nutritional backone of the country. The areas under crop is estimated to be 6-7million ha.This constitutes74%of the area under cereal and 45%of the total cultivated area in Sudan (Hamdoun andBabiker,1989). Sorghum grain has limited use for livestock. However, its use is limited, because starch and protein in sorghum is more difficult for animals to digest than the starches and protein in corn.

2.4 Classification of sorghum

Sorghum (*Sorghum bicolor* (L) Moench) is classified under the family *Poaceae*, tribe *Andropogoneae*, and genus *Sorghum* (Clayton and Renvoize, 1986; Adeyeye and Adesine, 2013). Snowden (1936) examined about 3000 specimens of cultivated sorghums collected together at Kew, UK, mainly from

the former British possessions in Africa and Asia. He recognized 31species, 157 varieties, and 571 forms, and published a classification system which provided the basis for many later schemes. Murty *et al.,* (1967) classified and catalogued a world collection of sorghum using a modification of Snowden's system. However, many sorghum workers have found Snowden's classification extremely difficult to use because it includes too many names and many sorghums are not recognizable on sight, so these must be keyed out. These workers prefer a simplified classification based on characters of the spikelet and inflorescence suggested by Harlan and de Wet (1972). According to this simplified classification, *Sorghum bicolor* (L.) Moench is partitioned into five basic races and ten hybrid races (Table 2.1).

I- Bicolor race: -

The bicolor race is widely scattered throughout Africa. It is characteristically low yielding with poor grain quality. It may have been collected and distributed because of its sweet juicy stalk. Grains are elongate; sometimes slightly obviate nearly symmetrical dorsoventrally. Glumes clasping the grain, which may be completely covered or exposed as ¼ of its length at tip. The head is an open panicle.

II- Caudatum race: -

The caudatum race is dominant in parts of Sudan, Chad, Nigeria, and most of Uganda. Agronomically, it is one of the most important races. The grain is markedly asymmetrical, the side next to the lower glume is flat, the opposite side rounded and bulging; glumes ½ the length of the grain. Caudatum spikelets are found on a wide range of head types.

II- Guinea race: -

The guinea race is basically a West Africa race; it is the dominant race in the Savanna belt and a secondary center is found in East Africa and Malawi. Grains are flattened dorso- ventrally, sub lenticular in outline, twisting at maturity

nearly 90 degrees between gaping involute glumes that vary from nearly as long as to longer than the grain. The head is a very open panicle.

IV- Kafir race: -

The kafir race is a major race in East and South Africa. It is characterized by erect, elongated, mostly semi- compact and cylindrical panicles. Glumes are moderately coriaceous and much shorter than the grain. Plants are of medium height and high yield (Mann *et al.*, 1983).

V- Durra race: -

The durra race is the dominant race in Ethiopia and the Sudan. The durras are in many ways the most specialized and derived of all the sorghums and many useful characters are likely to be found in them (Harlan and de Wet, 1972). Grains are rounded obviate. Glumes are very wide, the tip of a different texture from the base and often with a transverse crease across the middle. The head is a compact panicle.

Table 2.1. Harlan and de Wet's scheme for the partitioning of the cultivated sorghum into basic and intermediate races.

Basic Race	Intermediate Race
Bicolor (B)	Guinea- bicolor (GB)
Guinea (G)	Caudatum-bicolor (CB)
Caudatum C)	Kafir-bicolor (KB)
Kafir (K)	Durra-bicolor (DB)
Durra (D)	Guinea-caudatum (GC)
	Guinea-kafir (GK)
	Guinea-durra (GD)
	Kafir-caudatum (KC)
	Durra-caudatum (DC)
	Kafir-durra (KD)

Source: Harlan de Wet, (1972)

2.5. Nutritional composition and health benefits of sorghum as food

Sorghum is an excellent source of energy, proteins, fiber, fat and vitamin B complex essential in energy metabolism (Charles *et al.,* 2006). Sorghum is rich in calcium, iron, zinc, copper, phosphorous, potassium, magnesium, sodium, manganese, foliate and vitamins A, C and E (Mohammed *et al.,* 2010). Sorghum is gluten-free and has been recommended for people with diabetic, celiac disease or other gastrointestinal disorders (Ciacci *et al.,* 2007). Celiac diseases characterized by mal-absorption of nutrients as a result of gut sensitivity to gluten protein in 3 wheats, rye, barley and oats. Sorghum is an excellent source of phytochemicals such as phenolic acids, anthocyanin's, phytosterols and policosanols which prevent colon cancer and reduce the risk of getting heart attacks by lowering cholesterol levels (Awika and Rooney, 2004; Dykes and Rooney, 2006).

2.6. Insect pests of sorghum:

Approximately 151 insect species are reported to infest sorghum in different parts of the world (Jotwani, *et al.,* 1980) but the species of economic importance are much fewer. The major ones include: shootfly *Atherigona saccata* (Rondani); stemborers, *Chilo partellus* (Swinhoe); *Busseola fusca* (Fuller), *Sesamia cretica* (lederer and *Sesamia calamistis* (Hampson): aphids, *Schizaphis graminum* (Rodani) and *Melanaphis sacchari*(Zehntner); the sorghum midge, *Contarinia sorghicola* (Coqullet) and several species of head caterpillars, grass hoppers, locust andstorage insect(Nwanze, *et al.*,1995).

Five stem borer species are Known in the Sudan. three Noctuidae sorghum stem borer *Sesamia cretica.* Pink stalk borer *Sesamia calamistis,* maize stalk borer Busseola fusca and two Pyralidae spotted stem borer *Chilo partellus* s and millet stem borer *Coniesta ignefusalis* (Ahmed, 2005).

2.6.1. The spotted stem borer (*Chilo partellus* Swinhoe):

2 .6.1.1. Description

The different developmental stages are described by Schmutterer (1969): Moth with yellowish – brown, rather slender body plate (1). Wings span about 20 - 25 mm. Forewings pale. Distal areas of wings with one or two transverse rows of small dark - brown dots. Hind wings white with marginal fringe. Male usually smaller and somewhat darker than female.Pupa shining brown.Egg oval, flat and whitish. Larva in fully -fed stage about 20 - 25 mm long Dorsal side with longitudinal rows of light- brown color plate (2).

2.6.1.2. Distribution

Chilo partellus is native to Asia where it is considered to be a pest of maize and sorghum (Arabjafari, 2007). It was reported first in Africa in 1930, in Malawi, and has since then spread to most countries in eastern and southern Africa including, Ethiopia, Kenya, Malawi, Mozambique, Somalia, South Africa, Sudan, Tanzania and Uganda (CAB,1977). In Sudan, it was found in Northern (Shendi, EL Damer, Gureir, etc.), KassalaProvince (Kassala, Gash delta, Kashm el Girba) and Gedarif. It is also, found in Wad Madani, Sennar, Kadugli, Torit, Juba and Yambio (Schmutterer, 1969).

2.6.1.3. Host plants

Chilo partellus is an important pest of sorghum and pearl millet in Asia and Africa. It also attacks wheat *Triticum spp*, maize *Zea mays*, Sugar – cane *Saccharum sp*, rice *Oryza sativa*, foxtail *Hordeum jubatum* finger – millets *Eleusine coracana* and various grasses including, Johnson grass *Sorghum halepense*, Guinea grass *Panicum maximum* and Napier grass *Pennisetum purpureum* (Harris, 1990).

Plate 1. Moth of the spotted stem borer (*Chilo partellus*)

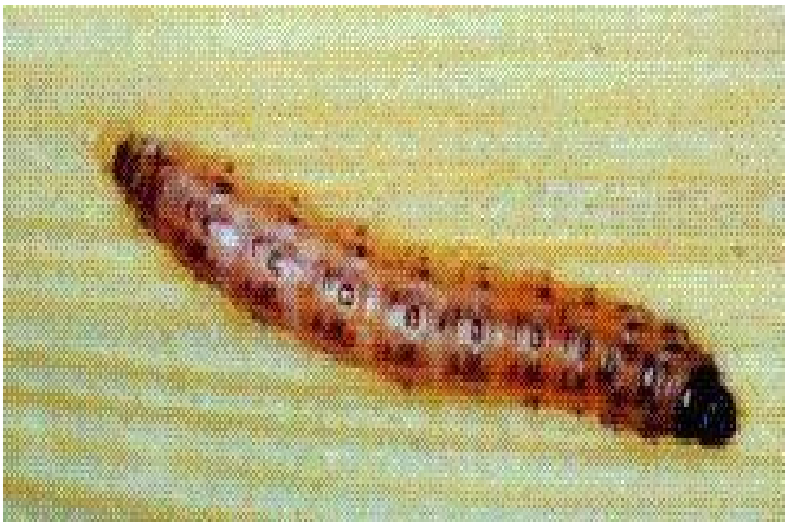

Plate .2 Larvae of the spotted stem borer (*Chilo partellus*)

Source: (Schmutterer,1969)

2.6.1.4. Life cycle

Adults come out from pupae in the late afternoon and early evening and are active at night. Female mate soon after emergence and oviposit on two to three subsequent nights, in batches of 10–80 overlapping eggs on the upper and undersides of leaves, mainly near the midribs. Adults live for about 2–5 days. Eggs hatch in the early morning (06:00 - 08:00) after 4 – 5 days (Harris, 1990), 4-8 days (Overholt, *et al.*,2001), and young larvae ascend plants to enter the leaf whorls, where they start to feed. Older larvae tunnel into the stem tissue. There are 5 -7larval instars reported by Sithole (1990) and after feeding for 21–25days (Schmutterer,1969) 2–3 weeks (Overholt, *et al.*,2001) pupae in the stems for 7 – 9 days (Schmutterer,1969), 5 – 12 days (Harris, 1990) under favourable condition. The life cycle showing in plate (3) is completed in 30- 40 days Sithole, (1990), 25-50days (Overholt, *et al.*,2001), Five or more successive generations may develop during the growing season. In cold and /or dry condition, larvae may enter a resting (diapause) in stems where they spend up to 6 months before pupation, (Overholt, *et al.*,2001).

2.6.1.5. Pest status and yield losses

The estimated yield losses due to *Chilo partellus* in sorghum exceed 50% (Revington, 1986). In Mozambique, *Chilo partellus*, the most important stem borer, was reported to cause severe damage on late planted sorghum that results in grain loss of 70% (Berger, 1981). Up to 80% grain loss in sorghum by *Chilo partellus* were observed in Kenya on 20 days – old crops (Seshu Reddy *et.al.*, 1989). In Zimbabwe *Chilo partellus* caused yield loss of 50 – 60 % in sorghum. In Burkina Faso and Niger, yield loss in sorghum by *Chilo partellus* was estimated by using carbofuran to protect the crop and by infesting the crop at different stage. The highest grain yield was obtained when the cropwas protected between 15 and 30 days after emergence. The infestation in unprotected plots was 60 – 62 % (Taneja and Nwanze ,1989). More damage by *Chilo partellus* was

observed on long season grain sorghum cultivars because of exposure over longer period in the susceptible pre flowering stage (van den *et.al*,1990).

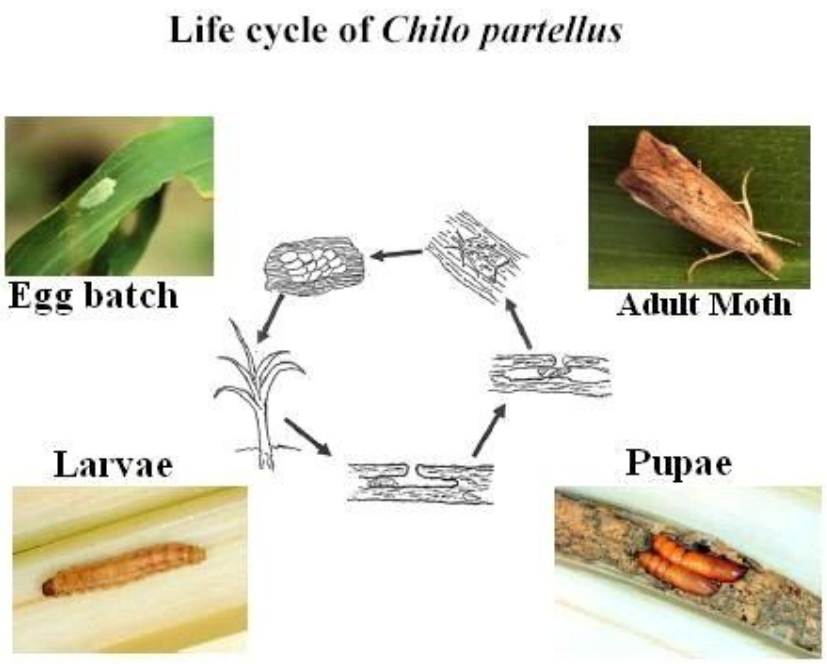

Plate 3. Life cycle of Stem Borer, *Chilo partellus*

Source: (Schmutterer,1969)

(source:http://www.cd3wd.com/cd3wd_40/Biovision/export/defaultct127$crops.html).

2.6.2. Dura stem borer (*Sesamia cretica* Ledrer);

2.6.2.1. Description

Moth 10-14 mm long. Wings span about 25-32 mm. Head, thorax, abdomen and forewings creamy white. Hind wings white showing in plate 4. Pupa shining brown. Larvae in fully- fed stage about 30-34 mm long, pink, white or yellowish - white. Head and spiracles brown showing in plate 5(Schmutterer ,1969).

2.6.2.2. Distribution

In Africa it was reported in Morocco, Egypt, Sudan, Somalia (Tams and Bowden,1953) and extreme northern Kenya (Nye,1960). Outside Africa it occurs in South and West Mediterranean, Yemen, Crete, India, Sri-Lanka and Thailand (Tams and Bowden,1953). In the Sudan, the moth occurs in the drier, irrigated parts, especially in the Northern and Central Sudan (Schmutterer, 1969).

2.6.2.3. Host plants

The main host plants of *sesamia cretica* were Sorghum *Sorghum bicolor*, maize *Zea mays*. Suger cane *Saccharum sp*, Wheat *Triticum sp* and rice *Oryze sativa* (Over holt, *et al.*, 2001).

2.6.2.4. Life cycle

The life cycle was described by Over holt, *et al.*, (2001). In 3 - 5 days, the female lays up to 350 eggs, deposited in batches of 10 – 40 eggs. The eggs are arranged in two to four contiguous rows and inserted between the lower leaf sheath and stem. Several hours after hatching, the larvae leave the ovipositional site to penetrate the stem. The larval stages, which lasts 30 – 60 days, usually involves five to six moults. Pupation generally takes place in the stem and lasts 10-12 days at 20C. Under tropical condition five to six generation are completed in a year. The life cycle is similar to that of *B. fusca* but young larvae tunnel directly into the stems soon after hatching, although some may feed on the leaf whorl and

upper leaves. Most recent research has been done in Egypt (Abul- Nasr *et al.*,1969) and the Sudan (Arsura *et al.*, 1977),

2.6.2.5. Pest status and yield losses

It was reported as a major pest of sorghum, and to a lesser extent maize.It is also, considered to be an important pest of sugar - cane in the Sudan (El Amin, 1984).

Plate 4 Moth of the dura stem borer (*Sesamia cretica*)

Plate 5 Larvae of the dura stem borer (*Sesamia cretica*)

(source:http://www.cd3wd.com/cd3wd_40/Biovision/export/defaultct127$crops.html).

2.6.3. Pink stem borer (*Sesamia calamistis* Hampson):

2 .6.3.1. Description

Moth with wingspan of 22-36mm showing in plate 6.Male usually smaller than female.Thorax and legs yellowish. Lateral margin of forewings often dark – brown. Basal and medium of forewing of the same color as thorax.Pupa a bout 30mm long.Dorsal surface pinkish to whitish (Schumetterer, 1969).

2.6.3.2. Distribution

*Sesamia calamistis*occurs throughout most of tropical Africa Country records include South Africa, Zimbabwe, Malawi, Uganda, Tanzania, Kenya Zanzibar, Madagascar, Mauritius, Reunion, Angola, Nigeria, Cote, Cameroon, Senegal, Gambia, Ghana, (Tams and Bowden,1953) Ethiopia Gebre - Amlak, 1985) In Sudan, it is found in Equatoria where it occurs mainly in the wetter area of the tree savanna (Schumetterer, 1969).

2.6.3.3. Host plants

The main host plants are, maize *Zea mays*, Sorghum *Sorghum bicolor*. Finger millet *Ecoracna*, rice *Oryza sativa*, Suger-cane *Saccharum sp.* (Nye,1960). Guinea grass *Panicum maximum* and Napier grass *Pennisetum purpureum* and Sudan grass *Sorghum vulagare var .sudanense*(Khan *et al.*, 1997). In the Sudan the southern pink borer attacks maize *Z. mays*, Sorghum *S. bicolor*and finger – millet *Eleusine coracana* (Schumetterer, 1969).

2.6.3.4. Life cycle

The female lays up to 350 eggs during 2-3days in batches of 10 – 40eggs. The eggs are inserted between the lower leaf sheaths and stem. Larval period lasts 30 - 60 days, depending on the climatic conditions. Pupation generally takes place in the stem. The pupal period last 10 – 12 days at 25C°. Five to six generations are completed in a year (Overholt, *et.al.*,2001).

Plate 6 Moth of the Pink stem borer (*Sesamia calamistis*)

2.6.3.5. Pest status and yield losses

The damage is caused by the young larvae by feeding on leaves whereas the older larva bore into the stem. Young sorghum plants often show dead heart effect. Older plants are stunted in growth, weakened and produce a low yield of poor quality (Schumetterer, 1969).

In the eastern and southern Africa, *Sesamia calamistis* is of moderate importance. Although it has a very wide distribution.*S. calamistis* is considered to be a very damaging borer in west Africa (Bosque- Perez and Schulthess,1998).

2.6.4. African maize stem borer (*Busseola fusca* Fuller):

2 .6.4.1. Description

Body and legs coppery – brown to grey brown, thorax with brown black and with three brown blackish waved transverse lines showing in plate (7).Larvae light or dark violet to pink or whitish plate (8).The segment with a number of dark warts from which fine hairs arise. Prothorax plate brown (Schmutterer, 1969)

2.6.4.2. Distribution

Busseola fusca is distributed widely throughout sub- Saharan Africa. Population in eastern and southern Africa appears to be adapted to different environments from those in west Africa. In the eastern and southern parts continent, B. *fusca* is restricted to mid – and high elevation areas (600m), whereas in West Africa, the same species is found at all elevations, but is most abundant in the drier savanna zone. Country records include Angola, Benin, Botswana, Burkina Faso, Cameroon, Mali, Mozambique, Nigeria, Rwanda, Ethiopia, Ghana, Guinea, Kenya, Lesotho, Malawi, Sierra, Leone, Somalia, South Africa, Tanzania, Uganda, Zaire, Zambia and Zimbabwe (Harris and Nwanze, 1992).

2.6.4.3. Host plants

Busseola fusca was recorded in Maize *Zea mays*, Sorghum *Sorghum bicolor*, Pear millet *Pennisetum glaucum* finger–millets *Eleusine coracana*, Sugar–cane *Saccharum sp*, Thatching grass *Hyparrhenia rufa*, Guinea grass *Panicum maximum* and Napier grass *Pennisetum purpureum* (Harris and Nwanze, 1992).

2.6.4.4. Life cycle

The female lays several hundred eggs in batches of 30 – 50 eggs, inserted between the sheath and the stem. Incubation lasts 1 week. After hatching the larvae feed on the young blades of the leaf whorl. Then they penetrate the stem by boring through the whorl base. After passing through six to eight stages in 30 - 45 days, they pupate in the tunnel. Pupation lasts 10 -20 days. Up to four generations are produced per year (Over holt, *et.al.*,2001).

Plate 7 Moth of the African maize stem borer*Buseola Fusca*

Plate 8 Larvae of African maize stem borer*BuseolaFusca*

(source: http://www.infonet-biovision.org/default/ct/102/pests)

2.6.4.5. Pest status and yield losses

In Tanzania, Jepson (1954) reported 40 -100 % sorghum plants infested by B. *fusca*, whereas in Ethiopia movement of *B. fusca* larvae into the base of sorghum head resulted in undersized heads and grain loss of 15% (Nagarkatti and Nair, 1973).

In Burundi, *B. fusca* occasionally caused yield losses of 30 – 50% (Muyango,1987). In the mid – and high elevation areas of eastern and southern Africa, *B. fusca* is often the most serious stem borer of maize, Yield losses have been estimated to be about 12%for every 10% of plant infested (Harris and Nwanze, 1992). In Zaire, losses of 8 – 9% in early – planted maize and 22 – 25 % in late – planted maize have been reported. In Cameroon, Cardwell *et al.*, (1997) reported grain weight loss as 4.6 g per borer in low land field and 8.7g per borer in high land fields.

2.6.5. Millet stem borer (*Coniesta ignefusalis* Hampson):

The millet stem borer, *Coniesta ignefusalis* (Hampson), is a damaging pest of pearl millet *Pennisetum glaucum* L.In the Sahelian and Sub Sahelian zones of Africa from Senegal to Sudan. There are usually three generations of the pest in a year in the wetter area (eg. Nigeria), and two occasionally three in the drier regions (eg.Niger) in Africa.

The damage is caused by larvae feeding on the stem plate (9). Towards the end of the rainy season, the larvae enter into diapause in the stems and stubbles and survive until the following rainy season (Youm, *et.al.*, 1996).

Plate 9 Larvaeof Millet stem borer (*Coniesta ignefusalis*)

(source: http://www.infonet-biovision.org/default/ct/102/pests)

2.7 Damage and symptoms of stem borers:

Stem borers damage plants by feeding on the leaves and in the stems and cobs, Early instars of larva of *Chilo partellus spp*. and *B. fusca* typically migrate from the ovipositor site to the whorl where they feed for the first two or three instars on the young succulent leaf tissue the damage becomes quite evident as the leaves mature and expand out of the leaf sheath. *Sesamia spp.* feed for a few days in the leaf sheath and then tunnel into the stem. The entrance holes chewed by larvae when entering the stem can often be seen, and in moist plants may be accompanied by fracases pushed out (Over holt, *et al.*, 2001). Prior to pupation, stem borer larvae chew an exit hole for the emergence of the moth. The hole is sometimes referred to as a window because it is not chewed completely through the stem but leaves the transparent leaf epidermis (Over holt, *et al.*, 2001).

2.7.1 Leaf damage

As soon as the larvae enter the young sorghum whorl they feed on the tender leaves near the base of the whorl. This feeding activity is later visible as elongated scars on expanded leaves (plate 10). This symptom is the first indication of the presence of stem borer larvae. Feeding activity continues in the whorl until the larvae reach the second or the 3rd instar (van Hamburg,1980). The feeding depends on the number of larvae reaching the whorl and the suitability of the genotype as s food source (Leuschner,1990). It has been reported that leaf injury by stem borer has no clear relationship with yield loss (Singh, *et al.*,1983; Ali,1992). Leaf feeding and overall plant damage was more acute at the young vegetative stages than the older ones (Alghali,1984).

2.7.2 Dead heart.

After having reached the second or third instar larvae leave the whorl to the base of the seedling where they bore into the seedling base at soil level or a few centimeters above (Leuschner,1990). Feeding inside the seedling base causes two

symptoms on the position of the growing point (Taneja and Wood head, 1987). If the floral initiation has taken place and the apical meristem has moved up words, larvae may feed only on the initial stem resulting in stem tunneling. If the apical meristem (grown point) is still present at the point of the larval entry it will be destroyed, causing dead heart which is characterized by dead of central leaves in young host plants (plate 11). Work in Zimbabwe has indicated that dead heart incidence in sorghum is greatest when the attack occurs before 26 days after crop emergence (Leuschner,1990). As the main stem died and the apical dominance is removed a number of tillers is usually formed on the plant. The earlier these tillers are formed the greater chance that they will synchronize with the main head development (Leuschner,1990). This mechanism serves as recovery mechanism according to Starks and Doggett (1970).

Plate 10. The Leaf damage by stem borers

Plate 11 . The deadheart damage by stem borers

2.7.3 Stem tunneling

Later the larvae penetrate into the stem in which they create tunnels by eating through the pith and vascular bundles that constitute the transport system for water metabolites (plate 12). Stem tunneling reduce plant vitality, the grain filling process and promotes lodging of plants as they mature. Damage to the inflorescence often interferes with grain filling and evident in sorghum plants that have complete or incomplete chaffy panicles depending on the extent of damage to the vascular bundles. The tunneling of the larvae in stem weaken the plants, many infested plants fall to the ground during heavy storms before harvest (Schmutterer, 1969). As long as feeding is restricted to pith grain fill will be normal or only slightly reduced. Weakened by tunneling, however, the peduncle may not be able to support the weight of the head and become especially susceptible to wind damage (Leuschner, 1990).

2.7.4. Entry and exit holes

After the stem borer larvae reach the second or third instar, larvae leave the whorl and migrate to the base of the seedling where they bore into the seedling base at soil level or a few centimeters above (plate 13). The loose or tight attachment of the lowest leaf sheath seems to be responsible to why the larvae sometime enter at the stem base and sometimes a few centimeters above. Genotypes with tight leaf sheaths tend to bore more basal entry holes. In genotyped with loose leaf sheath, larvae tend to enter behind the leaf sheath and bore into the stem a few centimeters above the base. Sometimes at the develop plant stage the larvae move up to three internodes below the whorl and enter the stem usually behind the leaf sheath close to the node (Leuschner,1990). After that the fully – grown larvae used to gnaw an exit hole, for the adult emergence, in the stem wall (Schmutterer,1969).

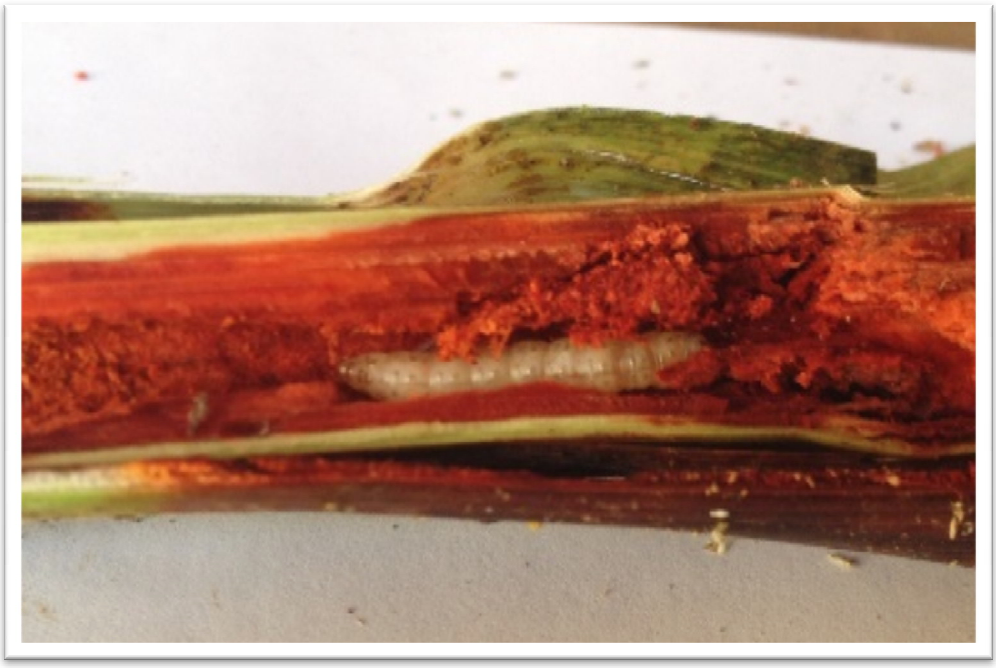

Plate 12. Stem tunneling damage by stem borers

Plate 13. Entry and exit holes by stem borers

2.8 Stem borer management approaches

There are several strategies methods for stem borer management. These include cultural practices such as intercropping, push and pull; biological control mainly introduction of parasitoids such as *Cotesia flavipes*; and use of chemical insecticides (Khan *et al.,* 2003; Tende *et al.,* 2005). Cultural control methods lower the insect pest infestation but do not effectively control the pests. Biological control methods are time consuming, laborious and the effects are obtained in the long run, when the insect has significantly caused damage to the crop (Mailafiya *et al.,* 2009). Chemical control is most effective if done before the damage is inflicted on the crop. Chemical insecticides are expensive to resource poor farmers and are associated with health and environmental risks (Karaya *et al.,* 2009). Host plant resistance is a viable option to insect pests‟ management in cereals since it is cheap to farmers, environmentally sound and generally compatible with other strategies of pest control (Tadele *et al.,* 2011).

2.9 Management of Stem borers

Control measures have been devised to minimize the economic impact of the damage caused by stem borers. Stem borers have been controlled by cultural, biological, host plant resistance and chemical methods (Bosque-Perez, 1995).

2.9.1 Cultural control methods

Cultural control is considered as the first line of defense against pests and includes techniques such as destruction of crop residues, inter cropping, crop rotation, manipulation of planting dates, and tillage method (van den Berg and Nur, 1998: Polaszek,1998). Many cultural control practices are labor intensive, but they have a little adverse effect on the investment in equipment. Uprooting, burning and ploughing in the crop residues are widely adopted methods, but only effective when applied at large scale.

2.9.1.1 Management of crop residues

Crop residues are important for carry over stem borer larval population from one growing season to the next. Control of *Busseola fusca* and *Chilo partellus* by burying old stalks and other crop residues immediately after harvest has been recommended (Ingram, 1958; Harris,1962 and Ajayi,1978).

In Nigeria, larvae of *Busseola fusca*, *Eldana saccharina* and *Sesamia calamistis* were found in crop residues below the soil surface, and higher incidences of these borers were observed in no-tillage plots (Kaufmann,1983). Slashing maize and sorghum stubble destroyed 70% of *Chilo partellus* and *Busseola fusca* population, and additional ploughing and disking destroyed a further 42% of the pest population in sorghum and 19% in maize (Kfir, 1988).

2.9.1.2 Tillage

Soil tillage may reduce insect population through mechanical damage, by burying them so deeply that they cannot emerge or bringing them to surface where they may be killed by weather factors, birds or other natural enemies. Tillage during the time when there are no crop growing will destroy volunteer plants, stubble and weeds that may provide food and breeding sites for stem borers from where they could infest newly planted crop (Lawani,1982). The effects of tillage on insects depend on the method and frequency of tillage and vary with insect species.

2.9.1.3 Time of planting

Cultural control based on time of planting, follows the principle of growing the crop when the pest is not present or planting at such a time that the most susceptible stage of crop development coincides with the time when the pest is least abundant. In the lower elevation of South Africa, it is recommended that sorghum should be planted after mid – October to avoid infestation from the first moth peak of *Chilo partellus* (van Hamburg,1979). In West Africa, early planting reduces *Busseola fusca* and *Sesamia calamistis* infestation (Abu, 1986). In the High Val region of South Africa, the second generation of *Busseola fusca* is larger and can cause more damage than the first generation (van Rensburg, *et al.*,

1988). At rainfed area the late sowing is not desirable because the yield of the late sowing crops is low even if free from stem borers (Seshu Reddy, *et al.*,1990). Haile, (2001) reported that sowing date had significant effect on stem borer incidence and damage levels. Early sowing dates had a significantly lower number of the larvae, infestation, dead heart and gave higher yield compared with the other sowing dates, while late sowing dates resulted in significantly higher infestation and damage.

2.9.1.4 Spacing

Spacing may affect the relative rate of development of plant and its pest population, for food or oviposition site (Lawani,1982). *Chilo partellus* first instars are known to migrate from hatching site to the funnel of the plant on which they hatched or to other plants within the vicinity (Ampofo, *et al.,* 1986). During this process as high as 100% mortality occurs (Mathez, 1972). A reduction in row width increased the number of larvae able to reach adjacent plant rows through migration, and this in turn resulted in more damage plants (van Rens burg, *et al.,* 1988). Increasing the spacing between adjacent plants would decrease the chance of the migration larvae coming in contact with neighboring plants. Consequently, fewer larvae would survive than if the plants were closely spaced. Wide spacing is very common in traditional farmer's field such as North Kordofan area (Per.Comm.). The lowest dead heart caused by *Busseola fusca* occurred at the lowest plant density in sorghum in South Africa (van Den Berg and Rens burg, *et al.,* 1991).

2.9.1.5 Intercropping

Intercropping or mixed cropping has been widely practiced for centuries by small scale farmers in Africa to reduce risk of crop failure, attain higher yield and improve soil fertility (Risch, *et al.,* 1983; Van den and Nur,1998). Some of these practices, also, lead to suppression of cereal stem borer population. Kato *et al.,* (1982) reported reduced stem borer oviposition, including *Chilo partellus*on sorghum intercropped with sesame compared with sorghum monocrop. Amoako

–Atta *et al.,* (1983) and Ogwaro, (1983) reported a significant delay in *Chilo partellus* colonization and establishment until 42days after germination (DAG) on cereals in different Cowpea and Sorghum intercropping combination compared with sorghum monocrop. The results obtained from the intercropping trails showed that planting sorghum and cowpea simultaneously or planting sorghum 2 weeks after cowpea, significantly delaye *Chilo partellus* larvae population build – up compared with that under mono crop sorghum. These results demonstrate the potentiality of intercropping host and non –host crops as cultural method of controlling *Chilo spp.*

2.9.2. Biological control methods

This is the action of natural enemies (parasites, predators and microbial agents) including naturally occurring agents and agents which are introduced and managed by humans for pest control (also referred to as "classical biological control") (Bosque-Perez, 1995). Example of using biological control methods for management of stem borers includes the use of natural enemies of stem borers such as Hymenoptera parasitoids to feed on their larvae, pupae and eggs (Greathead 1971; Jotwani 1978; Easwaramoothy and David, 1979; van Rens burg and Drinkwater,1987; Leslie,1988; Sithole ,1989; Sithole,1990; Smith *et al.*, 1993; Bosque-Perez, 1995; Bonhof *et al.,* 1997; Polaszek, 1998; Matama, 2000 and Zhou, *et al.*, 2001).

2.9.3 Host plant resistance methods

Host plant resistance is an important approach to pest management in gramineous crops confers many advantages (Bosque-Perez, and Schulthooss,1998). Resistance crop varieties provide an inherent control that involves no environmental problems and they are generally compatible with other insect control methods.

Mc culloch, (1923) reported that plant resistance to insect could be classified in two general categories. Natural resistance, which is shown by native plant or acquired by cultivated ones and artificial resistance that developed through

practical plant breeding. There is evidence that volatiles, color, water, vapor, physical structures and surface chemicals have an influence on *Chilo partellus* preference for oviposition (Saxena, 1985). Ovipositional non – preference to *Chilo partellus* has been reported on resistant genotypes by (Lal and Pant 1980). In a caged experiment, Harris (1989) found that oviposition was positively correlated with percentage of dead heart by *Chilo partellus.* Although, there is a preference for egg laying on plant surfaces, eggs can be deposited on any smooth metal or plastic surface.

It has been reported that stem borer tolerant sorghum cultivars showed significantly lower yield loss in spite of sever leaf injury and stem tunneling (Jotwani, *et.al.,* 1978; Dabrowski and Kidiavai, 1983 and Ali,1992).

. The occurrence of antibiosis as a dominant mechanism in borer resistance has been shown by detailed studies on survival and development of *Chilo partellus* larvae on susceptible and resistant varieties (Jotwani, *et al.,* 1971;1974). Mortality in the early larval stage was found to be significantly higher in resistant varieties and also the larval development was much slower compared to susceptible. The different varieties could even be rated for level of resistance based on larval growth index values.

Limited work has been carried out to determine possible chemical factors associated with antibiosis. Kalod and Pant (1967) found that sugar content in the resistant varieties was relatively lower though Swarup and Chaugale (1962) reported a higher sugar content in the resistant varieties to the stem borer. Combing ability analysis for damage caused by stem borer indicated the predominance of additive gene effect for stem borer were more important for resistance than non- additive gene effects for resistance to leaf damage, while stem tunneling is controlled by different gene effects (Singh and Verma,1988; Ali,1992). Rana and Murty (1971) indicated that leaf injury inherited by additive and additive X additive gene effect while stem tunneling is controlled by non-additive gene effect. A correlation between stem borer damage parameters,

reported by Ali (1992) indicated a positive correlation between the four symptoms of damage showed by stem borers. He, also, found that all stem damage parameters affected yield negatively (Gebrekidan 1982; Seshu Reddy 1983). In Uganda, Starks and Doggett (1970) made significant advances both in breeding methodology and the incorporation of resistance to *Chilo partellus*.

2.9.4 Chemical control methods

Under severe infestation, chemical control can provide an effective means of managing stem borers. However, chemical application is only effective if pest scouting and monitoring have been successful prior to crop damage. Furthermore, as stem borers burrow into the stem, they are often protected from insecticides applications. This control includes 20 the use of insecticide as well as other chemicals such as attractants and repellents (Bosque-Perez, 1995).

2.9.5 Integrated Pest Management (IPM)

This is the term used to describe the management of pests by integrating compatible control methods in an environmentally sound manner. Integrated pest management of stem borers combines cultural Biological, host plant resistance and chemical control methods to manage them. The used of insecticides is always the last resort in IPM control (Bosque-Perez, 1995).

2.10 Mechanisms of sorghum resistance to stem borers

Painter, (1951) recognized three mechanisms of resistance namely antibiosis, non-preference (antixenosis) and tolerance as described below.

2.10.1 Antibiosis

Antibiosis expressed in terms of larval and pupal mortality, decreased larval and pupal weights, prolonged larval and pupal development and reduced fecundity is an important component of resistance to stem borers in sorghum (Kumar *et al.*, 2006). Antibiosis factors function in leaf and

stem tissues (Dhillon *et al.,* 2006). Resistance to leaf and stalk feeding by European corn borer 12[Ostrinia nubilalis ((Hübner)] in temperate maize is conferred by 2, 4-dihidroxy-7-methoxy-1, 4-benzoxazin-3-one (DIMBOA) and increased concentrations of cell wall components mainly fiber and lignin (Krakowsky, *et al.,* 2007). High levels of total phenols, orthodehydroxy phenol and silica have associated with resistance to yellow stem borer in rice (Padhi, 2004). Sorghum genotypes namely ICSV 705, ICSV 714, IS 1044, IS 2205 and IS 18573 have been observed to demonstrate antibiosis to *C. partellus*in terms of reduced larval survival, development and feeding (Kumar *et al.,* 2007).

2.10.2 Antixenosis (non-preference)

Presence of antifeedants such as glycosides, alkaloids, terpenoids contribute to antixenosis mechanism of stem borer resistance in sorghum (Sharma, 2008). Chemicals in the leaf surface waxes (benzaldehyde, p-OH benzoate, and-CN-ion metabolites) protect sorghum against desiccation, disease and insect feeding and movement (Sanford and Reinhard, 2002; Kishore *et al.*, 2007). High contents of proanthocyanidins (PAs), 3-deoxyanthocyanidins (3-DAs), and flavan-4-ols in sorghum have been associated with sorghum resistance to biotic and abiotic stresses (Abdel *et al.,*2007). Trichomes and ligular hairs interfere with stem borers movement, feeding and oviposition (Muhammad, *et al.*, 2009). Increased leaf thickness, fiber and epidermalcell wall toughness impede feeding by stem borer neonate larvae in maize (Bergvinson, 2002).

2.10.3 Tolerance

Tolerance is where the plant is capable of supporting, without loss of yield or quality, a population of insect pests which would damage a susceptible variety (John *et al.*, 1994). Sorghum tillering following stem borer damage and in response to shoot flies is a component of tolerance (Kishore *et al.*, 2007). Components of tolerance include vigour, compensatory growth in infested plants, rapid lesion healing, changes in photosynthate partitioning and tissue mechanical support (Dhillon *et al.*, 2006). Sorghum tolerance to *C. partellus* damage has

been observed on IS 2205 after showing less grain yield reduction (Dhillon and Sharma, 2012).

2.11. Variability in Grain Sorghum

2.11.1 Genetic Variability

Genetic variability is essential to secure the success of any breeding program. Selection is not effective unless considerable genetic variation is present in the population**.** Evidence for the existence of considerable amount of variable in sorghum has been reported by many investigators, and the germplasm resources are still largely unexploited. Abuelgasim, (1989) reported that variation between sorghum genotypes were found in all studied characters (Tag El-Din and Hessen 2012). Berwal and Khairwal, (1997) in their study of genetic divergence in sorghum, where forty-two accessions were evaluated, found highly significant differences in plant height, number of tillers, stem diameter and leaf area. They predicated successful crosses between these accessions to improve each of these traits. Eight indigenous grain sorghum genotypes representing the types widely grown in kordofan and West White Nile districts of Sudan were studied by Ahmed, (2010). The result indicated a wide genetic diversity for all characters. Some genotypes from different clusters were superior in grain yield and some yield components. These genotypes could be recommended for further breeding programs. Highly significant ($P<0.01$) genotypic differences among the varieties for all the root and shoot morphological traits reported. Traits such as plant height, total root number, root volume. root dry weight, shoot dry weight and root to shoot weight ratio showed significant reduction. shoot dry weight, root dry weight, root number and root volume are biomass to conserve water and to increase water use efficiency (Blum,1988).

2.11.2 Phenotypic and Genotypic Variability in sorghum

Phenotypic variability in sorghum for yield and other traits has been reported by many workers (Sindagi *et al.*, 1970; Swarup *el al.* (1970); Harlan and

De Wet, 1972; Kambal and Abu El-Gasim, 1976; Yassin, 1978; Mahmoud, 1983; Gebesa, 1983; Abdalla, 1991; Bushara, 1999 and Al-Agab, 2005).Recently, a high level of diversity was reported in sorghum from Ethiopia (a primary center of origin), from India (a secondary centre of domestication) as well as from China, another important centre of diversity for sorghum (Ejeta *et al.*, 2004). They added, Sudan is recognized as a major centre of diversity and one of the most important centres of sorghum domestication and cultivation. Phenotypic variability is of a great importance for any successful sorghum breeding programme. This is because selection of desirable genotypes for hybrid industry will not be effective unless a considerable amount of variation is existing in the genotypes under investigation. In sorghum breeding programmes and hybrid development, sorghum breeders used a diverse inbred grown across a wide range of environments. Effects of environmental factors on phenotypic variability of sorghum were indicated by Foitz patrick and Nix (1969); Lewis *et al.* (1974) Eastin (1976)and Arunkumar, *et al.,* (2004). The variations occurring in segregating populations of cereal crops are attributable to three main sources: namely genetic effects, non-additive effects due to dominance and interaction of non-allelic genes, and environmental effects. The term genotypic variation is used throughout the study with reference only to the additive genetic or heritable variation responsible for progress resulting from selection. Phenotypic fluctuations may result from combinations of all types of variations, since the breeder is concerned with selecting superior genotypes.

2.11.3 Phenotypic (PCV) and Genotypic(GCV) Coefficient of variation

Genetic coefficient of variation (GCV), heritability and genetic advance expected from selection. Highly significant differences were obtained among the sorghum for all traits studied. Grain yield, stay green traits, panicle exertion and number of spikelet's per head showed a relatively high GCV and PCV (21-34%). The GCV was near to PCV for most of the characters, indicating a highly significant effect of genotype on phenotypic expression with very little effect of

environment heritability estimates observed for most of the character highly significant effect of genotype on phenotypic expression with very little effect of environment heritability estimates observed for most of the characters ranged from 47(stem thickness) to 95 percent (head length). Similar finding was also reported in sorghum by Haussmann *et al.*, (2002) for stay – green and yield per plant and Rao and Patil, (1996) for head length panicle exertion and plant height characters.

2.12. Heritability and Genetic Advance

Heritability is the proportion of the total phenotypic variance due to gene effects (Stanfield, 1988). It indicates the extent to which the expression of a character is under genetic control (Weber and Moorthy, 1952). Fehr (1987), reported that the heritability of a character has a major impact on the methods chosen for population improvement, inbreeding and other methods of selection. In sorghum heritability (h^2) and Genetic Advance (GA) were high for all the traits under well watering condition. Hence, for these characters, scope for selection is amenable, as the influence of environment on these traits was at very low extent; more uniform condition is expected to show higher heritability for the traits (Falconer,1996). Singh (1972) and Eckebil *et al*. (1977) reported that, high broad sense heritabilities were exhibited for blooming date and plant height. Sprague (1966) revealed that genetic variability is essential forany efficient plant breeding programme.

Heritability of all traits decreased from well watering to drought stress conditions as a results of increased environmental variance (Blum, 1988). Has revealed similar pattern of heritability decrease. Johnson *et al.,* (1955);,Fadlalla and Abdalla (1994).and Totok *et al.,*(1998) indicated that estimates of heritability along with genetic coefficient of variation are useful in predicting the resulting effects of sample size, environment, the character and population on heritability estimates. Moreover, heritability value indicates the confidence with which selection of genotypes can be based on phenotypic performance. However,

estimation of heritability in broad sense has limitation because it includes both additive and epistasis gene effects (Abraham *et al.*, 1998). Comparatively high heritability (63- 99%) were obtained from all traits except for green leaf area at 15 days after flowering (GLA15), days to 50%flowering and yield, which showed moderate heritability value (52- 57%). Therefore, estimates of heritability in broad sense would be more meaning if accompanied by estimates of genetic coefficient of variation. High GCV along with high heritability and genetic advance provide better information than other parameters alone. On the basis of the present study, stay –green parameters (%GLA15, %GLA30 and %GLA45), yield per plant, panicle exertion, head length and 1000 seed weight are the more important quantitative characters to be taken into consideration for effective selection in sorghum. Opportunities to improve these traits appear to be likely through the degree varies depending on $h^2$and GCV values (Addissu, 2011).

2.13. Phenotypic correlation

The variations occurring in segregating populations of cereal crops are attributable to three main sources: namely additive genetic effects, non-additive effects due to dominance and interaction of non-allelic genes, and environmental effects. The term genotypic variation is used throughout with reference only to the additive genetic or heritable variation responsible for progress resulting from selection. Phenotypic fluctuations may result from combination of all types of variations. Abraham *et al.*, (1998) found that genotypes correlation coefficient was slightly higher than the association with days to 50% flowering, productive tillers/plant, days to maturity and 1000- grain weight. The positive genetic association of grain yield with flowering and maturity dates indicates limitation in development of early maturity types and high grain yield.

CHAPTER THREE

MATERIALS AND METHODS

3.1. Field Survey:

Specific survey wasconducted to evaluate the status of the stem borers infestation on sorghum in different sites in Khartoum State (longitude 34º:31" E; latitude 15º:75" N) during July-December 2015/2016 (Fig.1).

A total of Sites areas in Khartoum State were surveyedAl Khadroo, El fakei Hashim, Shambat, Seleet Scheme (north Khartoum) Soba (east Khartoum) El Gezira Islang(north Omdurman), Toti Island (central Khartoum) and Tiba (south Khartoum) to evaluate the status of the stem borers infestation on sorghum during Autumn 2015/2016.

3.1.1. Cross sampling

For each site 3 plots were randomly chosen. In each plot the cross sampling method was applied. Ten plants were randomly chosen along each cross line. In each plant 3 leaves (one upper, one middle, and one lower) were checked for damage caused by two Lepidopteran stem borers, *Chilo partellus* and *Sesamia cretica*. Then infestation was recorded as infested (Plate 3-1) or non – infested leaves (Plate 3- 2) to assess the incidence and distribution of stem borer in Khartoum State in Sudan.

3.1.2. Survey Analysis

On the basis of observed data, per cent infested leaves were computed and analyzed by using Statistix 8.0 software package; also means separation was carried out using Duncan's multiple Ranges Test (DMRT).

3.2. Genetic materials used in the study

The plant materials used in this study were 22 Sorghum (*Sorghum bicolor* L. Moench) genotypes. The 15 genotypes were exotic materials maintained in the Agriculture Research Corporation (ARC) – Shambat. Seven genotypes wereprovided by the Sorghum Breeding Program of Agriculture Research Corporation (ARC) - wed Medani. The origin of the genotypes is shown in Table 3.1.

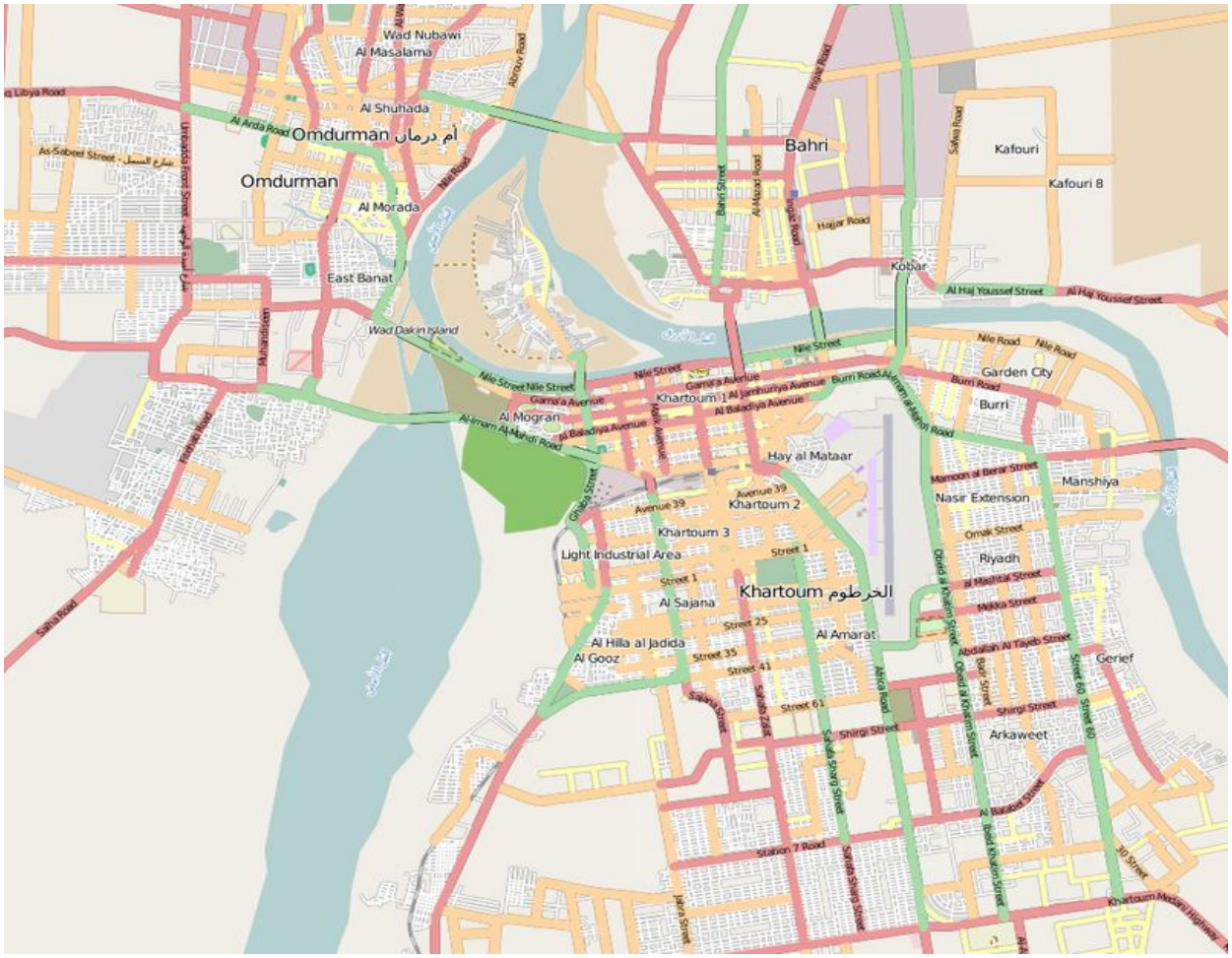

Fig. (1) Map of Khartoum State locations

Source: http // www.researchgate-net/figure/map of state of Khartoum -Sudan.

Plate (3-1). Sorghuminfestedleavesby stem borer

Plate (3-2) Non - infested leaves

Table 3.1 Sorghum genotypes used in the study in Shambat

Entry code	Genotypes	Source
1	F -1	*(ARC) – Shambat
2	F- 2	*(ARC) – Shambat
3	F -3	*(ARC) – Shambat
4	F- 4	*(ARC) – Shambat
5	F -5	*(ARC) – Shambat
6	F- 6	*(ARC) – Shambat
7	F -7	*(ARC) – Shambat
8	F- 8	*(ARC) – Shambat
9	F -9	*(ARC) – Shambat
10	F-10	*(ARC) – Shambat
11	F-11	*(ARC) – Shambat
12	F- 12	*(ARC) – Shambat
13	F -13	*(ARC) – Shambat
14	F-14	*(ARC) – Shambat
15	F-15	*(ARC) – Shambat
16	G.1.1.4	**(ARC) - wed Medani
17	G.1.1.16	**(ARC) - wed Medani
18	G.2.13.5	**(ARC) - wed Medani
19	G.1.1.13	**(ARC) - wed Medani
20	Tabat	**(ARC) - wed Medani
21	W. Ahmad	**(ARC) - wed Medani
22	Arfa Gadamk	**(ARC) - wed Medani

*** Agriculture Research Corporation (ARC). Shambat Research Station, Sudan**

**** Agriculture Research Corporation (ARC) - wed medani**

3.2.1. Field experiments

3.2.1.1 Field experiments site:

The study was conducted in the Experimental Farm of the College of Agricultural Studies, Sudan University of Science and Technology, Shambat (longitude 32º:31"E; latitude 15º:39" N; and 380m above sea level) (Sayed, 2012) Fig. 1. The soil at Shambat site is heavy clay with Ph8.5. Shambat climate is semi-arid.

3.2.1.2 Climate and Weather Conditions:

The climate of the region is semi-arid and subtropical having mild Winter. The rainfall occurs mostly from mid-June to end of September. The average maximum and minimum temperatures are 31.7°C and 20.1°C respectively. The meteorological data regarding the temperature.relative humidity and rainfall were recorded during the cropping season bythe meteorological observatory located at college of agriculture farm and presented in appendix (1)

3.2.1.3 Description of Experiments of the study

Two field experiments were made in this study;the first was conducted during Autumn season (*kharif*) and the second with in during Winter season of 2016/2017.The experiments were conducted at the Experimental Farm of the College of Agricultural Studies, Sudan University of Science and Technology, Shambat.

3.2.1.4 Cultural practices, layout and experimental design:

The experiments were laid out in a Randomized Complete Block Design (RCBD)with three replications in each season. The experimental site was disc ploughed, disc harrowed and leveled. Ridging up was north-south. The plot size was 4 rows,2 meters long. Plants were spaced 20 cm between holes and 70 cm between ridges. Seeds were sown on the 17 th of July 2016 and 15th of November 2016 for the Autumn and Winter sowings respectively. Seeds rate applied were (2.5 kg/fed). Five seeds were placed in holes spaced at 20 cm along the eastern side of ridge and the seedlings were later thinned to approximately 2

plant/hole.Nitrogen fertilizer (urea) 40kg/F was applied in one dose two weeks after planting added at the second irrigation at the rate of80 kg/fed three weeks after planting. Hand weeding was frequently done to get rid of weeds including Bermuda grass (*Cynodondactylon*), Hut grass (*Cyperus rotundus*) and Striga (Bouda) (*Strigahermontheca*).Inthe second season the insecticides (Traicel) was sprayed to control Aphid Insect pest. Irrigation was applied at 7 to 10 days' interval. However, some sporadic rains were recorded at Shambat.

3.3. Data recorded:

3.3.1. Method of observation:

The following observation was recorded to screen the advanced sorghum resistance against stem borers (*Chilo partellus* Swinhoe) and (*Sesamia cretica* Ledrer).

During growth period two types of observations viz. leaf injury and dead heart formation were recorded on the 20th, 40thand 60th days after emergence to work out the per cent plant infestation and per cent dead heart caused by stem borers.

At harvest fiverandomlyselected plants/plot were split open longitudinally with the help of a knife and total tunneled were recorded and later converted in to percent tunneling. On the basis of observed data, per cent stem tunneling was computed and transformed in arc sine for statistical analysis

3.3.1.1 Percentage of infested plants (IP%)

$$IP\% = \frac{\text{No. of infested plants/plot}}{\text{Total No. of plants /plot}} \times 100$$

Lines were classified according to their mean IP% into:

Resistant (Less than 35%)

Moderately resistant (from 35% to less than 70%)

Susceptible (70% or above) (Al- Naggar *et a*l., 2000)

3.3.1.2 Percentage of dead hearts (DH %)

$$DH\ \% = \frac{\text{No. of plant with dead hearts/plot}}{\text{Total No. of plants /plot}} \times 100$$

Lines were classified according to their mean DH% into:

Resistan (Less than 7 %)

Moderately resistant (from 7% to less than 15%) and

Susceptible (15% or more)(Al- Naggar *et a*l., 2000)

3.3.1.3 Intensity of damage (ID %) as follows

According to Al- Naggar *et al.,* (2000). Six class rating scale was used for evaluating the amount of plant injury in maize caused by *S. cretica* larvae attack. The description of this scale is as follows:

Class 1: No visible injury on plants (no symptoms).

Class 2: plants with holes less than 0.5 mm in diameter across partially or fully un folded whorl leaves.

Class 3: Several folded and unfolded whorl leaves with relatively wider round holes.

Class 4: Several folded and unfolded whorl leaves with relatively larger round or elongated holes accompanied with small yellowish- green pillets of frass aggregated in the whorl.

Class 5: Plants with relatively larger round and / elongated irregular holes, evident distortion of the leaves (most leaves have long holes), withering of whorl and accumulation of comparatively large sized pillets of frass in the whorl or on the ground around the stem.

Class 6: Plants with dead heart.

The intensity of damage (ID)value for each plot was calculated as follows:

$$ID = \frac{ID1 + ID2 + \ldots\ldots\ldots\ldots + IDn}{N}$$

Where ID1, ID 2,……ID n denote intensity of damage of the infested plant No.1,No.2,……..No. n and N= number of plants / plot.

Lines were classified according to their ID into: resistant (to less than 1.7 ID), moderately resistance (1.7 to less than 2.7 ID) and susceptible (2.7 ID or above) (Al- Nagger *et al*.,2000).

3.3.2. Statistical Analysis

The data obtained from a set of observations for each character were tabulated and analyzed by the method of Analysis of Variance shown in Table 3-2 as suggested by Fisher and Yates, 1938.

Table 3.2 Skeleton of ANOVA table

Sources of Variance	Degree of freedom	Sum of square (S.S.)	Mean sum of square (M.S.S.)	Calculated Value	F value	Table Value
Replications	(r-1)	SSR	MSR	MSR/MSE		
Treatments	(t- 1)	SSTr	MSTr	MSTr/MSE		
Error	(r-1)(t-1)	SSE	MSE			
Total	(rt -1)					

The significant differences between different treatments were judged by using critical differences (C.D) which was calculated as follows:

$$S.Ed = \frac{\sqrt{MSE}}{r} \times \sqrt{2}$$

S.Ed = Standard error of differences between two treatments mean

MSE (ve) = Error mean sum of square (Error variance)

C.D. =*For treatment at 5% = S.E.d* × *t(d.f.) at 5%*

Where,

R = Number of replication

T = Value of fisher's table for error degree of freedom at 5%

d.f. = Error degree of freedom

C.D. = Critical difference

3.4. Agronomic data

Agronomic data recorded in both growing seasons under natural infestation condition were: Plant height (cm), Stem diameter (cm), Leaf area (cm^2), days to 50% flowering (day), days to physiological maturity,1000- grain weight (g) and grain yield (ton/ha.). The data collected were statistically analyzed according to (Gomez and Gomez, 1984). And the treatment was compared by least Significant Difference (L.S.D.) at 5% level.

3.4.1. Measurements of growth attribute:

Five plants were randomly selected from the two inner ridges at each plot leaving out 50 cm at each end of the plot. The selected plants were tagged. To avoid bird damage. The emerged heads on tagged plants were covered by cloth bags. Data were recorded for the following parameters in both seasons.

3.4.1.1. Plant height (cm):

The plant height was measured from the base of the main stem to the tip of panicle usingtape meter, and then the mean plant height was calculated for each plot.

3.4.1.2. Number of leaves/plant:

The five plants used for the measurement of plant height were also used for counting the leaves per plant and the average numbers of leaves were recorded.

3.4.1.3. Stem diameter (cm)

Measured at the middle of fixed internodes (third from the bottom using digital Vernier caliper.(Plate 3-3).

3.4.1.4. Leaf area (LA) (cm^2):

Leaf area for three leaves per plant of the five plants per plot was measured. For each leaf, the maximum length was multiplied by the maximum width and then multiplied by 0.75 to obtain the leaf area (Sticker, 1961).

$$\text{Leaf area(LA)} = \text{Maximum Length} \times \text{Maximum Width} \times 0.75$$

3.4.1.5. Number of Days to 50%flowering (days).

The days of 50% flowering were recorded from sowing date up to the day when50% of the plants at each plot had fully exerted heads.

3.4.1.6. Number of Days to physiological Maturity (days):

They were taken as the number of days from sowing date to the day when all the heads at each plot had reached physiological maturity.

3.4.1.7. Head excretion (cm):

The length of the peduncle from the flag leaf to the base of head, average for five plants per plot at physiological maturity was recorded.

3.4.2 Grain yield and related traits

3.4.2.1. Paniclelength (cm)

The length of panicle from the base to top was recordedfor five plants and the average was considered.

3.4.2.2. Panicle Width (cm)

The panicle was measured at the widest part of the head.

3.4.2.3. Panicle weight (g)

The weight of the panicles of five plant of each genotype at each plot was determined as average, using sensitive balance. (Plate 3-4)

3.4.2.4 Thousand Seeds weight(g);

Weight was done by randomly taking seed from the bulk of seeds of each selected five plants. Thousand seeds were randomly taken and their weight was recorded, using sensitive balance.(Plate 3-4).

3.4.2.5 Grain yield per m^2(g)

It was estimated by the following formula:

$$= \frac{\text{Grain yield per plot (g)}}{\text{Plot area } (m^2)}$$

3.4.2.6. Grain yield (ton/ha)

After harvesting all the covered heads from an area of 0.70 m² in the middle ridges of each plot were cut and stored for four weeks to minimize change in weight due to moisture content manually threshed, cleaned weight by using the sensitive balance and the grain yield Ton/ha was determined as the following formula:

$$\text{Grain yield (t/ha)} = \frac{\text{(Grain weight /plot)} \times 10000}{\text{Plot area}}$$

3.5 Statistical analysis:

As described by Steel and Torrie (1980). The analysis of variance (ANOVA) appropriate for Randomized complete blocks Design (RCBD), with three replications was carried out on the collected data which analyzed by using Statistic 8.0 software package, also means separation was carried out using Duncan's multiple Ranges Test (DMRT). Estimates of the phenotypic, genotypic, and environmental components of variance were calculated on the basis of the mean expectations shown in Table 3-3 as suggested by Snedecor and Cochran. (1971).

3.5.1 Coefficient of variation: (C.V %):

It was determined for each character in both seasons using the formula

$$CV\% = \frac{\sqrt{(MSE)} \times 100\%}{(G)}$$

Where:

MSE =mean square of Error, G= Grand mean.

3.5.2 Comparison between seasons:

The means were separated using the least significant difference (LSD) at 5% level of significance according to the formula:

$$CV\% = \sqrt{2} \times \frac{\text{Error Mean Square}}{r} \times t$$

Where:

r=number of replicationst= level of significance for t-value at 0.05

Table (3.3) ANOVA and the expectations of variance components in the Sorghum variability study at Shambat, 2016-17

Source of variation	Degree of freedom	Mean Square	EMS Expected mean squares
Replications	**(r-1) = 2**	**M3**	
Treatment	**(t-1) =21**	**M2**	**g ^{2}σ e+ ^{2}σ**
Error	**(r-1)(t-1) =21**	**M1**	**g ^{2}σ**
Total	**(Rt-1)=42**		

Where:

M1, M2, M3, M4, M5, M6= Mean squares for replication, treatments and error, respectively.

ANOVA: analysis of variance

r = number of replications

t = genotypes

MS = Mean square

EMS= Expected mean square

^{2}σ e = error variancee

^{2}σg = genotypic variance

Plate 3-3 Digital Vernier Caliper.

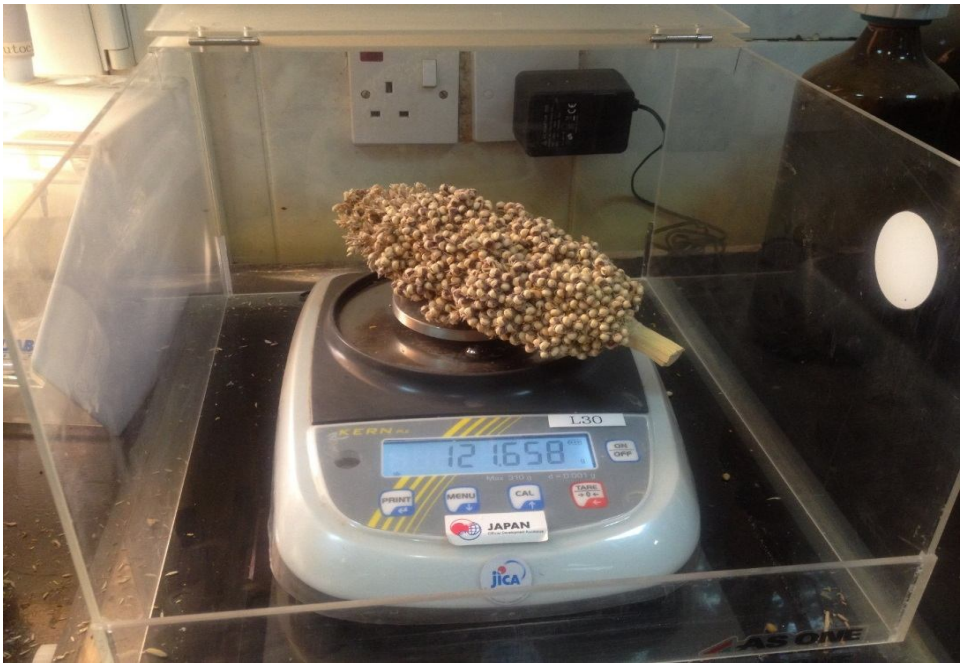

Plate 3-4 Sensitive Balance.

3.6 Phenotypic (σ²ph) and genotypic (σ²g) variances

The phenotypic variance (∂ 2p) was calculated by adding genotypic variance to environmental variance as suggested by Mathur *et al.* (1971) and Singh and Chaudhury (1999).

$$ph = \sigma^2 g + \sigma^2 e \ ^2\sigma$$

The genotypic variance (∂ 2g) was calculated by subtracting the mean sum of squares for the error (∂ 2e) from the mean sum of squares for varieties and dividing the remainder by the number of replications as in the following formula used by Burton and De Van, (1953) ; Virk *et al.* (1971)and Singh and Chaudhury (1999).

$$g = (M_2 - M_1)/r \ ^2\sigma$$

Where:

g = genotypic variance²σ

g²e = error or environmental variance.

r= number of replications

M1, M2= Error and genotypes mean squares, respectively.

3.7 Phenotypic and genotypic coefficient of variation (%):

They were according to formula suggested by Burton and Devane, (1953) as follows:

*** Phenotypic coefficient of variation (PCV) =**

$$\frac{\sqrt{\sigma\ ^2 Ph} \times 100}{Grand\ mean}$$

*** Genotypic coefficient of variation (GCV) =**

$$\frac{\sqrt{\sigma^2 g} \times 100\ \%}{Grand\ mean}$$

Where σ ²Ph is phenotypic variance

And σ²g = genotypic variance

The PCV and GCV values are ranked as low, medium and high (Sivasubramaian and Menon 1973) and are mentioned below:

0 – 10% Low

10 – 20 % Moderate

>20 % High

3.8 Heritability (h^2B):

Broad sense heritability (h^2) was estimatedin each trait according to Johnson *et al.,* (1955), using the formula:

$$\mathbf{h}^2 = \frac{\sigma^2 g}{\sigma^2 ph}$$

where:

$\sigma^2 g$ = genotype variance,

$\sigma^2 ph$ =phenotypic variance.

The heritability percentage was categorized as low moderate, and high as suggested by Robinson *et al*., (1949) as follows:

0 – 30 % low :31 – 60 % Moderate and above: High

3.9 Phenotypic correlation

It was to estimates phenotypic between two seasons. They were used further for computation of phenotypic correlation between different characters, using the formula suggested by Miller *et al.*, (1958) coefficients between pairs of different traits were determined, according to the formula suggested by Miller *et al*. (1958).

Phenotypic correlation of coefficient

$$(r\ ph) = \frac{\sigma^2 phxy}{\sqrt{(\sigma^2 phx)\ (\sigma^2 phy)}}$$

Where:

$\sigma^2 phxy$ = phenotypic covariance between two traits (x, y).

$\sigma^2 phx$ = phenotypic variance for trait x.

$\sigma^2 phy$ = phenotypic variance for trait y.

CHAPTER FOUR

RESULTS

4.1 Field survey:

Field survey of putative *Chillo partellus* and *Sesamia cretica* were carried out in different sites in the Khartoum State. A total of eight Sorghum growing areas in Khartoum State were surveyed. These are Al Khadroo, El fakei Hashim Shambat, Seleet Scheme (north Khartoum) Soba (east Khartoum) El Gezira Islang (north Omdurman) Toti Island (central Khartoum) and Tiba (South Khartoum). The aim was to evaluate the status of the stem borer's infestation on sorghum during Summer 2015/2016.

The results of survey and identification indicated that, only two species of stem borers were found inall locations in the study area.and showed that, the Sorghum crop in the study sites were infested by both stem borers (*Chilo partellus* (Swinhoe) and *Sesamia cretica* (Led.), with variable degrees of infestation (Table 4.1). The highest infestationin all surveyed sitesaues in Shambat (60.34%) and the lowest infestationwere noted in Soba (31.7%). Table (4.1), Figure (4-1) and appendix (2)

4.2. Prevalence of *C. partellus* and *S. cretica* in Khartoum State:

The *Chilo partellus*damage **(**Plate 4-1**)**, *Sesamia cretica* damage (Plate 4-2) was found to have a wide distribution in the Khartoum State on Sorghum along the eastern, western, southern and northern were found highly infested by the (*Chilo partellus* and *Sesamia cretica*). According to the results shown in Tables (4-1, 4-2) , Figures (4-2, 4-3) and Appendixs (3, 4) there was a significant difference between the number of *Chilo partellus* and *Sesamia cretica*.

Table 4.1: Stem borer infestation (%) on sorghum at different sites in Khartoum State (Autumn 2015/2016)

Site	Infestation %
Toti Island	38.38%^{DE}
Gezira Islang	48.99%^{B}
Shambat	60.34%^{A}
Seleet Scheme	42.95%^{CD}
El khadroo	46.14%^{BC}
EL fakei Hashim	44.19%^{BC}
Soba	31.70%^{F}
Tiba	33.83%^{EF}
C.V.	6.09
SE $\pm$	2.156
LSD	4.6248

Plate 4-1. The *Chilo partellus* damage

Plate 4 -2. The *Sesamia cretica* damage

Table (4.2): Mean infested Sorghum leaves percentage attacked by *Chilo. partellus and Sesamia cretica*.

Site name	*Chilo partellus*	*Sesamia cretica*
Toti Island	43.67^{C}	33.08^{CD}
Gezira Islang	52.43^{B}	43.69^{B}
Shambat	65.25^{A}	59.99^{A}
Selait Scheme	46.67^{BC}	38.56^{BC}
El khidro	49.05^{BC}	44.89^{B}
EL fakey hasim	48.92^{BC}	39.83^{B}
Soba	33.26^{D}	30.37^{D}
Teba	34.5^{D}	33.18^{CD}
C.V.	7.8	11.01
SE $\pm$	3.006	3.6361
LSD	6.4489	7.7986

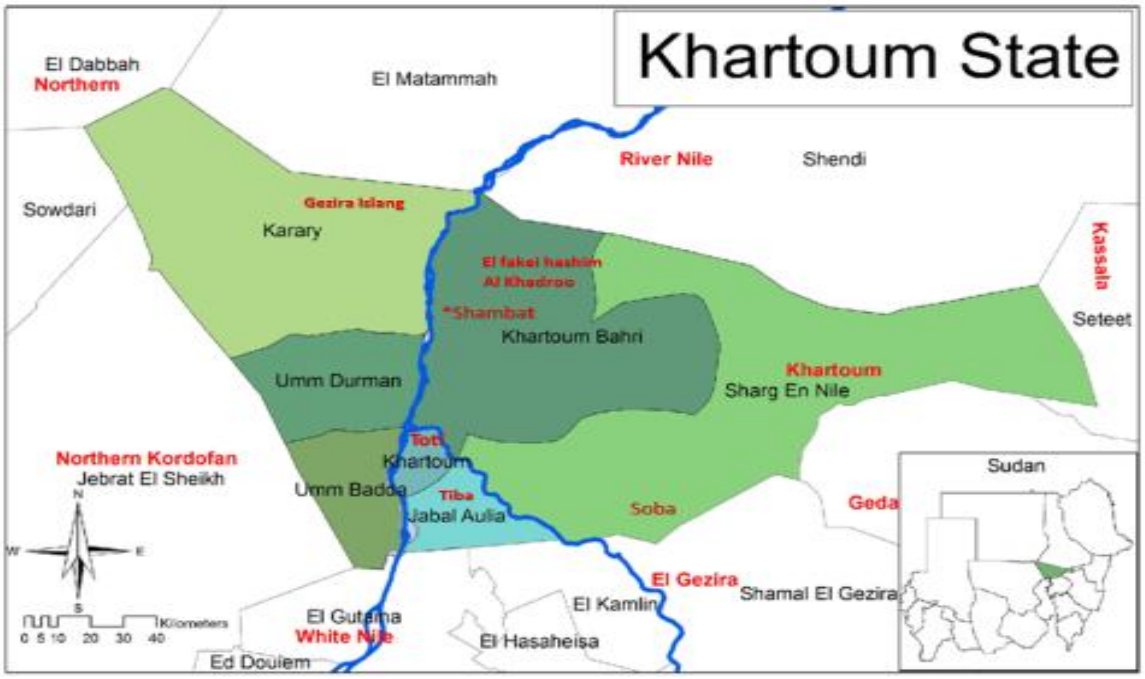

Fig. (4-1) Stem borers infestation (%) on sorghum at different study sites in Khartoum State

Source: http // www.info.xxx-org.Accessed20 thMay2018

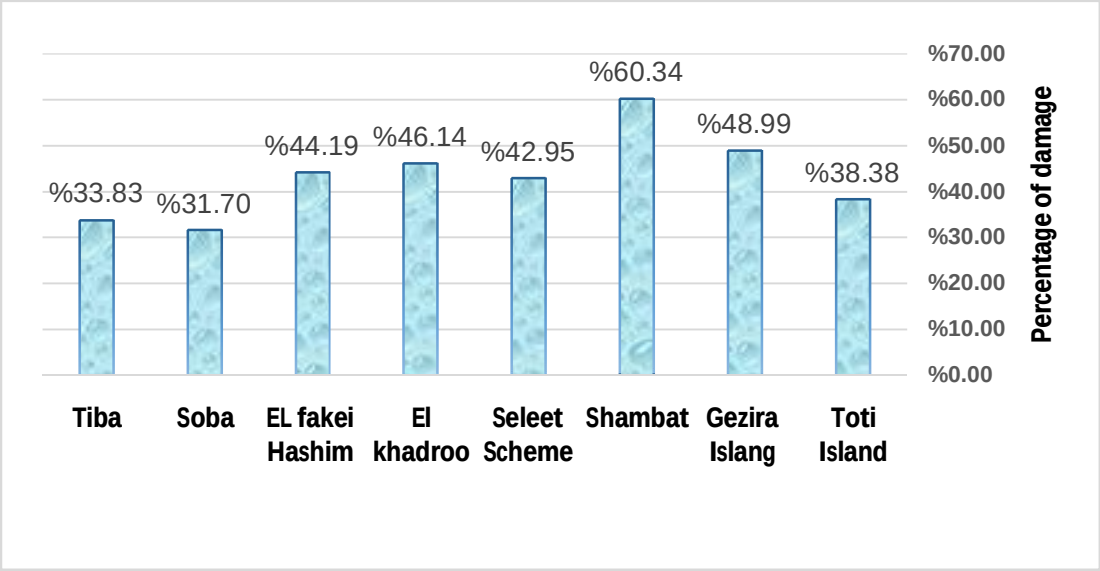

Fig. (4-2): The mean incidence of infestation caused by stem borers in eight locations in Khartoum State during 2015/2016

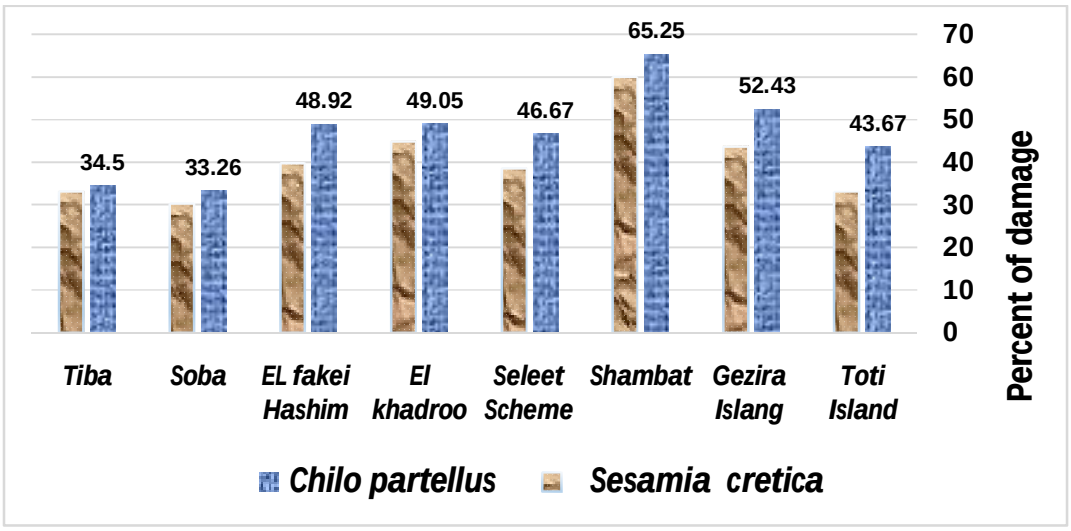

Fig. (4-3): Percent damage caused by *C.partellus* and *S.cretica* on Sorghum

4.3 Field experiment:

The present experiment entitled, “Screening of sorghum [*Sorghum bicolor* (L.) Moench] genotypes against stem borers (*Chillo partellus* Swinhoe and *Sesamia cretica* Led.) was conducted during *(Autumn- Winter)* season 2016-2017 at the Experimental Farm of the College of Agricultural Studies, Sudan University of Science and Technology, Shambat, Sudan. Appendices (5- 6). The observations were recorded on infestation caused by stem borers (*Chilo partellus* and *Sesamia cretica*).To screen the relative resistance /susceptibility and to identify the most promising genotypes among the entries for their susceptibility to stem borers.

4.3.1 Observation

The first incidence of leaf and stem damage was recorded on leaf on 20 th to 60 th. The larvae continue to feed on stem and peduncle till the maturity of crop.

4.3.1.1 Leaf Injury (%)

Leaf damage is mostly caused by initial instar larvae. They cause pin hole or short holes in the leaf /leaf whorl. A uniform damage on the leaf area was observed. In order to measure leaf damage, a visual rating scale was used. Scales include nine different types of parameters. Most of the genotypes had damage symptoms on three to four leaves or more.

The data recorded on leaf damage percent show significant difference among tested genotypes in Autumn season (Table 4-3, Figure 4.3 and appendix 7). The minimum leaf injury was recorded in G.1.1.4 (4.87%). The maximum injury was recorded in F-6 (8.74%)**.** It was proved by the studies that G.1.1.4, Tabat and G.1.1.16 average leaf ratings of these genotypes were 4.87, 5.00, 6.04 were least susceptible and F-6 was most susceptible for leaf damage. While in Winter season, the minimum leaf injury was recorded in G.1.1.4 (5.21%). The maximum injury was recorded in F-6 (8.80%) ,as seen inTable 4-4, Figure 4.4 and appendix 8.

Table (4.3) Average of leaf injury rating at 20,40 and 60 th caused by stem borers in 22 Sorghum genotypes during Autumn (*kharif*) 2016/2017.

Entry No.	Genotype		Leaf Injury (%)		
			20 th	40 th	60 th
1	F -1	Agriculture Research Corporation – Shambat (ARC)- Medani	3.60^{FG}	5.77^{GHI}	6.97^{FG}
2	F -2		5.14^{BCDE}	6.64^{CDEF}	7.15^{E}
3	F -3		4.42^{DEF}	6.25^{EF}	8.12^{BCD}
4	F -4		4.52^{CDEF}	5.81^{GH}	7.39^{EF}
5	F -5		4.30^{DEF}	5.94^{GH}	6.5^{GH}
6	F -6		6.50^{A}	8.05^{AFGH}	8.74^{A}
7	F -7		4.20^{DEF}	6.02^{FGH}	7.24^{EF}
8	F -8		4.80^{CDEF}	7.41^{AB}	8.56^{AB}
9	F -9		5.70^{ABC}	7.12^{BC}	8.27^{ABC}
10	F -10		5.10^{BCDE}	$5.14I^{J}$	6.52^{GH}
11	F -11		6.33^{AB}	6.33^{DEFG}	7.92^{CD}
12	F -12		4.43^{DEF}	5.78^{GHI}	6.63^{G}
13	F-13		4.4^{DEF}	6.9^{BCD}	8.25^{ABCD}
14	F -14		4.74^{CDEF}	7.31^{BC}	8.35^{ABC}
15	F -15		4.52^{CDEF}	7.36^{B}	8.67^{A}
16	G.1.1.4		0.22^{H}	3.50^{K}	4.87^{I}
17	G.1.1.16		2.74^{G}	4.73^{J}	6.04^{H}
18	G.2.13.5		4.11^{EF}	5.37^{HIJ}	6.90^{FG}
19	G.1.1.13		5.40^{ABCD}	6.97^{BCD}	7.94^{CD}
20	Tabat		1.32^{H}	3.71^{K}	5.00^{I}
21	W.Ahmad		5.21^{BCDE}	6.40^{DEFG}	7.75^{DE}
22	Arfgadamk		4.11^{EF}	6.31^{DEFG}	7.28^{EF}
	Mean		**4.37**	**6.13**	**7.32**
	C.V.		**17.56**	**6.68**	**4.26**
	SE+		**0.6278**	**0.3347**	**0.2545**
	LSD 0.05 %		**1.2669**	**0.6755**	**0.5135**

Table (4.4) Average of leaf injury rating at 20th,40th and 60th caused by stem borers in 22 Sorghum genotypes during Winter 2016/2017.

Entry No.	Genotype		Leaf Injury (%) 20 th	40 th	60 th
1	F -1	Agriculture Research Corporation - Shambat	4.96 ^{DEF}	5.93^{EFGH}	7.50^{EFG}
2	**F -2**		5.15 ^{DE}	6.65^{DE}	8.14^{BCD}
3	F -3		5.13 ^{DE}	6.16^{EFGH}	8.09^{CD}
4	F -4		5.11 ^{DE}	6.39^{EF}	7.30^{FG}
5	F -5		4.98 ^{DEF}	6.41^{EF}	6.58^{H}
6	**F -6**		6.69 ^{A}	7.46^{BCD}	8.80^{A}
7	F -7		4.87 ^{DEF}	5.70^{FGH}	7.16^{G}
8	F -8		5.75 ^{ABCDE}	7.61^{BC}	8.82^{A}
9	F -9		5.99 ^{ABCD}	6.77^{CDE}	8.32^{ABCD}
10	F -10		4.81 ^{EF}	5.50^{GH}	7.01^{GH}
11	F -11		6.44 ^{ABC}	7.55^{BC}	8.56^{ABC}
12	**F -12**		4.91 ^{DEF}	6.16^{EFG}	7.21^{G}
13	F-13		5.20 ^{DE}	7.43^{BCD}	8.37^{ABC}
14	F -14		5.41 ^{CDE}	7.83^{AB}	8.65^{AB}
15	F -15		6.59 ^{AB}	8.51^{A}	8.73^{A}
16	**G.1.1.4**	**(ARC)**- Medani	1.26 ^{H}	3.75^{I}	5.21^{J}
17	**G.1.1.16**		3.55 ^{G}	4.41^{I}	5.95^{I}
18	G.2.13.5		5.27 ^{DE}	6.04^{EFGH}	7.00^{GH}
19	G.1.1.13		5.93 ^{ABCDE}	7.27^{BCD}	7.81^{DEF}
20	Tabat		3.91 ^{FG}	5.40^{H}	5.6I^{J}
21	W.Ahmad		5.13 ^{DE}	6.32^{EFG}	8.00^{CDE}
22	Arfgadamk		5.50 ^{BCDE}	6.67^{DE}	8.12^{BCD}
	Mean		**5.1194**	**6.4583**	**7.5935**
	C.V.		**(13.72)**	**(7.93)**	**(4.49)**
	SE+		**0.5733**	**0.4184**	**0.2782**
	LSD 0.05 %		**1.1570**	**0.8444**	**0.5614**

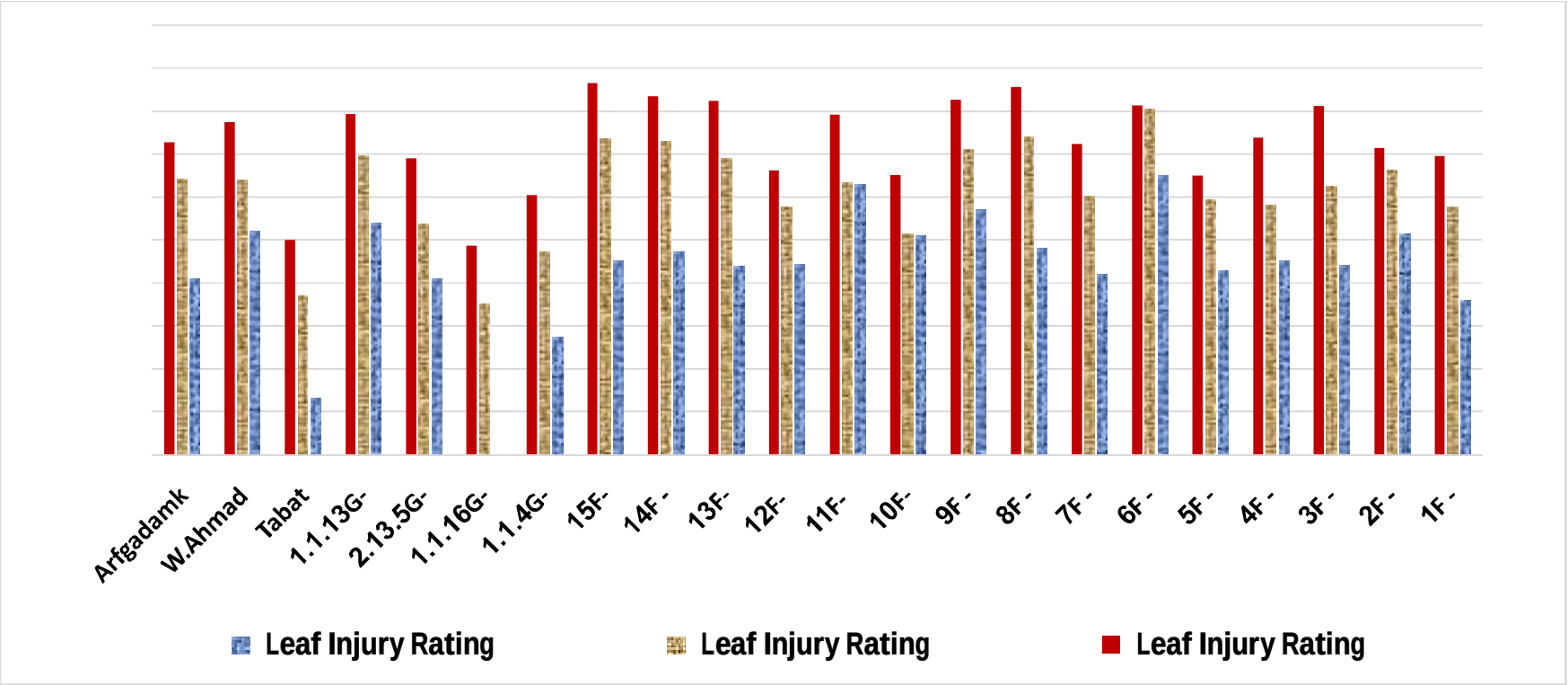

Fig. (4-4) Leaf Injury Rating on 20,40,60 Days after planting in Autumn season

X axis =genotypes Y axis = rating scale

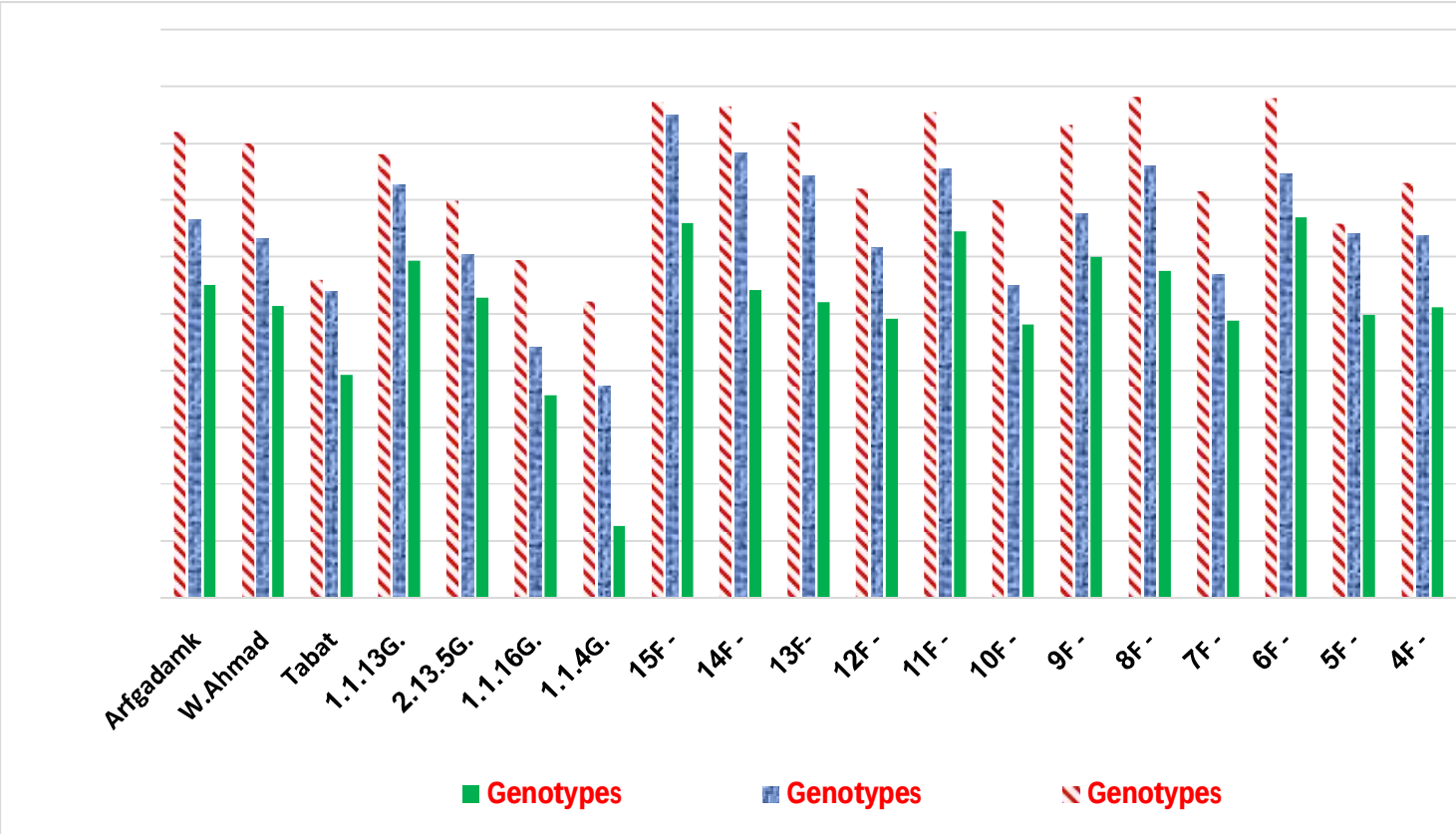

Fig. (4-5) Leaf Injury Rating on 20,40,60 Days after planting in Winter season

X axis =genotypes Y axis = rating scale

4.3.1.2 Infested Plants (IP) (%)

Results in Tables (4-5, 4-6 and 4-9) showed that, in Autumninfestation, only eight genotypes, i.e. G.1.1.4, Tabat, G.1.1.16, G.2.13.5, F-1. F-5, F-12 and F-10 were significantly resistant, while all other genotypes were moderately resistant. However, in Winter season infestation only four genotypes, i.e. G.1.1.4, G.1.1.16, Tabat and F-10 were significantly resistant, while all the other genotypes were significantly moderately resistant. The mean data across the two seasons indicated that, six resistance genotypes were detected (G-1.1.4, Tabat, G-1.1.16, F-10 F-5 and G-2.13.5) with an average (13.65.20.14, 22.44, 33.69, and 34.45) respectively and 16 moderately resistant genotypes (F-12, F-1, F-7, F-4, Arfa gadamk, F-3, W. Ahmad, F-2, F-1-13, G-1.1.13, F-9, F-1-14, F-11, F-8, F-15, F-6) with an average of (35.15,35.03,35.4,35.5, 35.92,38.31,41.68,42.49,43.15,43.22,48.15, 48.51, 50.53 ,51.96 ,52.59, 53.5, 57.12, 60.37). Fig.(4-9) and Appendices (7, 8)

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4.3.1.3 Plant with Dead Hearts (DH) (%)

Results for resistance in Autumn season, the minimum dead heart % was found in Arfagadmk (2.58%) followed by F-7 (2.59%). Maximum infestation was found in F-6 (4.21%). The percent dead heart showed that only four genotypes, i.e. Arfa gadamk, F-7, Tabat and G.1.1.4 were significantly resistance, while all the other genotypes were moderately resistant, except F-6.whih was susceptible with 17.7%(4.21%)dead heart formation.While in Winter season, the minimum dead heart % was found in G.1.1.4 9.70% (3.12%) followed by Tabat 10.0% (3.17%). Maximum infestation was found in F-6 24.9% (4.99%).Data recorded on the percent dead heart show that only seven genotypes, i.e. (G.1.1.4, Tabat, G.1.1.16, F-9, F-1, F-13 and F-7) were moderately resistant, while the other genotypes were highly susceptible. Since leaf damage was present on most of the genotypes, wheas dead

heartsymptoms were on a small number of plants, it can be conclouded that the larvae started feeding on genotype thenmajority of them died or left the plants which result in lower dead heart symptom. The plant growth and development and hampered considerably after a critical level of damage.Details of data regarding dead hearts is shown in Tables 4 -7, 4-8 and 4-9, Figure 4 -7 and Appendices 7, 8.

4.3.1.4 Mean Tunnel Length (Stem tunneling) (%)

Stem tunneling % wassignificantly different among the genotypes. The minimum and maximum stem tunneling in Autumn season was found in Tabat 5.61 (2.38%) and F-6 28.28(5.32%) respectively. While, minimum and maximum stem tunneling in Winter season was found in G.1.1.4 6.56 (2.57%) and F-8 28.86 (5.38%).

Considering the tunnel length all the genotypes were classified in to three categories. Tunnel length between 0-5 cm was consider as least susceptible, tunnel length between 5-10cm are moderately susceptible, whereas plant with more than 10 cm tunnel were highly susceptible. Sixteen genotypes, F -5, F- 2, G.2.13.5, F-13, F-7, F-1, F-4, F-9, F-3, Arfagadmk, F-11, F-14, F-8, F-15, G.1.1.13 and F-6 were highly susceptible. Six genotypes Tabat.G.1.1.4, G,1,1,16, F-12, F-10 and W. Ahmed were moderately susceptible. The data of stem tunneling it shown in Tables 4-10, 4-11 and 4-12, Figures 4-8, 4-9 and appendices (7, 8 and 9)

4.3.1.5 Intensity of damage (ID)

Results on intensity of damage Table 4-9) revealed that, in Autumn seasons only one genotype (G.1.1.4) was resistant, eight genotypes were moderately resistant while all other genotypes were susceptible. Results in Winter season showed that only one genotype (G.1.1.4) was significantly resistant, seven genotypes (G.1.1.16, F-5, Tabat,F-12, G.2.13.5, F-10, and F-4) were moderately resistant, while all other genotypes were susceptible.
Data mean across the two seasons showed that, only one genotype (G.1.1.4) was resistance, eight genotypes were moderately resistant (G.1.1.16, F- 5, Tabat, G.2.13.5, F-12, F-4, F-1 and F- 7) with an average of (1.90, 2.37, 2.45, 2.48, 2.50, 2.59,2.63 and 2.70) respectively. and 13 genotypes were susceptible (F-2, Arfa gadamk, W. Ahmad, F-10, F-3, F-11, G.1.1.13, F-13, F-14, F-15, F-8, F-9 and F-6) with an average of (2.86, 2.87, 2,88, 2.92, 2.96, 2.99, 3.06, 3.9, 3.13, 3.28, 3.28, 3.30 and 4.04) respectively, Figure 4-9, appendices 7, 8 and 9. Results showed also that,scores for the three resistant traits were much higher in Winter as compared to Autumn season infestation.

Table (4-5): Percentage of infested plants affected by *Chilo parterllus& Sesamia cretica* in different Sorghum genotypes during Autumn season 2016-17

Genotype	Infested plants	Relative rating	Rank
F -1	**31.99**	**R**	5
F -2	**40.60**	**M**	12
F -3	**41.66**	**M**	13
F -4	**36.37**	**M**	11
F -5	**32.35**	**R**	6
F -6	**61.59**	**M**	22
F -7	**35.69**	**M**	9
F -8	**50.64**	**M**	20
F -9	**50.69**	**M**	21
F -10	**33.12**	**R**	8
F-11	**47.91**	**M**	17
F- 12	**32.38**	**R**	7
F-13	**45.47**	**M**	15
F -14	**48.57**	**M**	18
F-15	**50.06**	**M**	19
G-1.1.4	**12.18**	**R**	1
G-1.1.16	**22.24**	**R**	3
G-2.13.5	**31.19**	**R**	4
G-1.1.13	**47.29**	**M**	16
Tabat	**14.50**	**R**	2
W.Ahmad	**42.82**	**M**	14
Arfgadamk	**36.28**	**M**	10
C.V.	**9.22**		
LSD	**5.82**		

R= resistant M = moderate S =susceptible

Table (4-6) Percentage of infested plants affected by *Chilo parterllus& Sesamia cretica* in different Sorghum genotypes during Winter season 2016-17

Genotype	Infested plants	Relative rating	Rank
F -1	**38.81**	**M**	9
F -2	**45.85**	**M**	13
F -3	**43.32**	**M**	11
F -4	**40.26**	**M**	10
F -5	**36.74**	**M**	6
F -6	**59.39**	**M**	21
F -7	**36.15**	**M**	5
F -8	**56.36**	**M**	19
F -9	**50.38**	**M**	16
F -10	**34.27**	**R**	4
F-11	**57.28**	**M**	20
F- 12	**38.23**	**M**	8
F-13	**50.83**	**M**	17
F -14	**55.36**	**M**	18
F-15	**64.33**	**M**	22
G-1.1.4	**15.12**	**R**	1
G-1.1.16	**22.65**	**R**	2
G-2.13.5	**38.11**	**M**	7
G-1.1.13	**49.73**	**M**	15
Tabat	**25.77**	**R**	3
W.Ahmad	**43.48**	**M**	12
Arfgadamk	**47.09**	**M**	14
C.V.	**9.48**		
LSD	**6.74**		

R= resistant M = moderate S =susceptible

Table (4-7): Percentage of dead hearts affected by (*Chilo parterllus& Sesamia cretica)* in different sorghum genotypes during Autumn season 2016-17

Genotype	Plants with Dead heart	Relative rating	Rank
F -1	13.20(3.64)	M	19
F -2	14.40(3.80)	M	20
F -3	8.46(2.92)	M	7
F -4	11.56(3.41)	M	16
F -5	9.76(3.14)	M	11
F -6	17.70(4.21)	S	22
F -7	6.90(2.56)	R	2
F -8	12.13(3.49)	M	18
F -9	9.10(3.02)	M	8
F -10	9.66(3.12)	M	9
F-11	10.50(3.25)	M	14
F- 12	9.73(3.12)	M	10
F-13	9.83(2.97)	M	12
F -14	14.49(3.83)	M	21
F-15	12.03(3.47)	M	17
G-1.1.4	7.06(2.67)	M	4
G-1.1.16	7.53(2.75)	M	5
G-2.13.5	11.16 (3.35)	M	15
G-1.1.13	10.06(3.19)	M	13
Tabat	7.002.89(2.66)	M	3
W.Ahmad	8.33(2.86)	M	6
Arfgadamk	6.60(2.58)	R	1
C.V.	**17.36**		
LSD	**0.8890**		

* Figures in parenthesis are arc sign values

R= resistant M = moderate S =susceptible

Table (4-8): Percentage of dead hearts affceted **by (*Chilo parterllus& Sesamia cretica)* in different sorghum genotypes during Winter season 2016-17**

Genotype	Plants with Dead heart	Relative rating	Rank
F -1	14.3(3.79)	M	5
F -2	18.2(4.27)	S	13
F -3	19.8(4.46)	S	19
F -4	19.7(4.44)	S	17
F -5	15.13(3.90)	S	9
F -6	24.9(4.99)	S	22
F -7	14.7(3.84)	M	6
F -8	16.9(4.12)	S	11
F -9	14.1(3.76)	M	6
F -10	16.7(4.09)	S	10
F-11	17.5(4.19)	S	12
F- 12	19.2(4.39)	S	16
F-13	14.3(3.79)	M	4
F -14	19.2(4.39)	S	16
F-15	21.4(4.63)	S	21
G-1.1.4	9.70(3.12)	M	1
G-1.1.16	10.8(3.29)	M	3
G-2.13.5	19.7(4.44)	S	18
G-1.1.13	20.4(4.50)	S	20
Tabat	10.0(3.17)	M	2
W.Ahmad	19.1(4.38)	S	15
Arfgadamk	18.9(4.35)	S	14
C.V.	**21.10**		
LSD	**1.39**		

* Figures in parenthesis are arc sign values

M = moderate S =susceptible

Table (4.9): Average of infested plant, plants with dead hearts and intensity of damage under natural infestation during two successive seasons (Autumn –Winter) 2016-17

	Genotypes	Infested plant						Dead heartsPlants with						Intensity of damage					
		Autumn		Winter		Mean		Autumn		Winter		Mean		Autumn		Winter		Mean	
		IP%	.	IP%		IP%		DH%		DH%		DH%		ID		ID		ID	
1	F -1	31.99	R	38.81	M	35.4	M	13.2	M	14.3	M	13.75	M	2.55	M	2.71	S	2.63	M
2	**F -2**	40.60	M	45.85	M	43.225	M	14.4	M	18.2	S	16.3	S	2.82	S	2.89	S	2.86	S
3	F -3	41.66	M	43.32	M	42.49	M	8.5	M	19.8	S	14.15	M	2.94	S	2.98	S	2.96	S
4	F -4	36.37	M	40.26	M	38.315	M	11.6	M	19.7	S	15.65	S	2.56	M	2.61	M	2.59	M
5	F -5	32.35	R	36.74	M	34.545	R	9.8	M	15.13	S	12.46	M	2.44	M	2.3	M	2.37	M
6	**F -6**	61.59	M	59.15	M	60.37	M	17.7	S	24.9	S	21.3	S	4.01	S	4.06	S	4.04	S
7	F -7	35.69	M	36.15	M	35.92	M	6.9	R	14.7	M	10.8	M	2.65	M	2.74	S	2.70	M
8	F -8	50.64	M	56.36	M	53.5	M	12.1	M	16.9	S	14.5	M	3.27	S	3.29	S	3.28	S
9	F -9	50.69	M	50.38	M	50.535	M	9.1	M	14.1	M	11.6	M	3.26	S	3.33	S	3.30	S
10	F -10	33.12	R	34.27	R	33.695	R	9.7	M	16.7	S	13.2	M	3.23	S	2.61	M	2.92	S
11	F -11	47.91	M	57.28	M	52.595	M	10.5	M	17.5	S	14	M	2.97	S	3	S	2.99	S
12	**f3 -12**	32.38	R	38.23	M	35.305	M	9.7	M	19.2	S	14.45	M	2.47	M	2.52	M	2.50	M
13	F-13	45.47	M	50.83	M	48.15	M	8.8	M	14.3	M	11.55	M	3.07	S	3.1	S	3.09	S
14	F -14	48.57	M	55.36	M	51.965	M	14.6	M	19.2	S	16.9	S	3.08	S	3.15	S	3.12	S
15	F -15	50.06	M	64.33	M	57.195	M	12	M	21.4	S	16.7	S	3.27	S	3.29	S	3.28	S
16	**G.1.1.4**	12.18	R	15.12	R	13.65	R	7.1	M	9.7	M	8.4	M	1.48	R	1.52	R	1.50	R
17	**G.1.1.16**	22.24	R	22.65	R	22.445	R	7.5	M	10.8	M	9.15	M	1.81	M	1.98	M	1.90	M
18	G.2.13.5	31.19	R	38.11	M	34.65	R	11.2	M	19.7	S	15.45	S	2.43	M	2.53	M	2.48	M
19	G.1.1.13	47.29	M	49.73	M	48.51	M	10.1	M	20.2	S	15.15	S	3.04	S	3.07	S	3.06	S
20	Tabat	14.50	R	25.77	R	20.135	R	7	M	10	M	8.5	M	2.41	M	2.48	M	2.45	M
21	W.Ahmad	42.82	M	43.48	M	43.15	M	8.3	M	19.1	S	13.7	M	2.87	S	2.89	S	2.88	S
22	Arfgadamk	36.28	M	47.09	M	41.685	M	6.6	R	18.9	S	12.75	M	2.82	S	2.91	S	2.87	S
	Mean	**38.43**		**43.16**		**40.795**		**10.28**		**17.026**		**13.653**		**2.79**		**2.81**		**2.80**	
	c.v	**9.22**		**9.48**		**9.35**		**29.72**		**29.07**		**29.395**		**4.81**		**4.34**		**4.58**	
	SE+	**2.8924**		**3.34**		**3.115**		**2.49**		**4.04**		**3.265**		**0.1098**		**0.0998**		**0.10**	
	LSD	**5.83**		**6.74**		**6.285**		**5.037**		**8.15**		**6.5935**		**1.2507**		**0.2013**		**0.73**	

R= resistant M = moderate S =susceptible

Table (4-10): Range of mean tunnel length(cm) in different sorghum genotypes

S. NO	Range of mean tunnel length	Genotye name
1	0 – 5(Least Susceptible)	-
2	5 -10 (Moderately Susceptible)	Tabat.G.1.1.4,G,1,1,16, F-12, F-10, W.Ahmed,
3	>10 (Highly Susceptible)	F -5, F- 2, G.2.13.5,F-13, F-7,F-1, F-4 ,F-9, F-3,Arfagadmk, , F-11, F-14, F-8, F-15, G.1.1.13,F-6

Table (4-11): Stem tunneling % caused by stem borers in different Sorghum genotypes in Autumn season

Genotype	Stem tunneling	Relative rating	Rank
F -1	17.01(4.13)	S	12
F -2	13.83(3.73)	S	8
F -3	18.06(4.26)	S	15
F -4	17.44(4.18)	S	13
F -5	13.82(3.72)	S	7
F -6	28.28(5.32)	S	22
F -7	16.52(4.07)	S	11
F -8	24.02(4.91)	S	19
F -9	17.57(4.20	S	14
F -10	8.8(2.97)	MS	5
F-11	19.51(4.42)	S	17
F- 12	7.54(2.75)	MS	4
F-13	15.09(3.89)	S	10
F -14	20.04(4.48)	S	18
F-15	25(5.00)	S	20
G-1.1.4	5.96(2.45)	MS	2
G-1.1.16	6.39(2.54)	MS	3
G-2.13.5	13.87(3.73)	S	9
G-1.1.13	26.52(5.15)	S	21
Tabat	5.61(2.38)	MS	1
W.Ahmad	9.35(3.07)	MS	6
Arfgadamk	18.43(4.30)	S	16

* Figures in parenthesis are arc sign values

R= resistant M = moderate MS = moderately susceptible S =susceptible

Table (4- 11): Stem tunneling % caused by stem borers in different sorghum genotypes in Winter season

Genotype	Stem tunneling	Relative rating	Rank
F -1	18.5 (4.31)	S	14
F -2	15.69 (3.97)	S	9
F -3	18.88 (4.35)	S	15
F -4	17.32 (4.17)	S	11
F -5	14.17 (3.77)	S	7
F -6	28.5 (5.34)	S	20
F -7	18.1(4.26)	S	13
F -8	28.86 (5.38)	S	22
F -9	17.71(4.21)	S	12
F -10	8.92 (2.99)	MS	5
F-11	20.17(4.50)	S	17
F- 12	8.33(2.89)	MS	4
F-13	16.11(4.02)	S	10
F -14	20.46 (4.53)	S	18
F-15	28.67(5.36)	S	21
G-1.1.4	6.56 (2.57)	MS	1
G-1.1.16	7.06 (2.67)	MS	3
G-2.13.5	15.45 (3.94)	S	8
G-1.1.13	26.78 (5.18)	S	19
Tabat	6.98 (2.69)	MS	2
W.Ahmad	10.25(3.21)	MS	6
Arfgadamk	19.92(4.47)	S	16

* Figures in parenthesis are arc sign values

R= resistant M = moderate MS = moderately susceptible S =susceptible

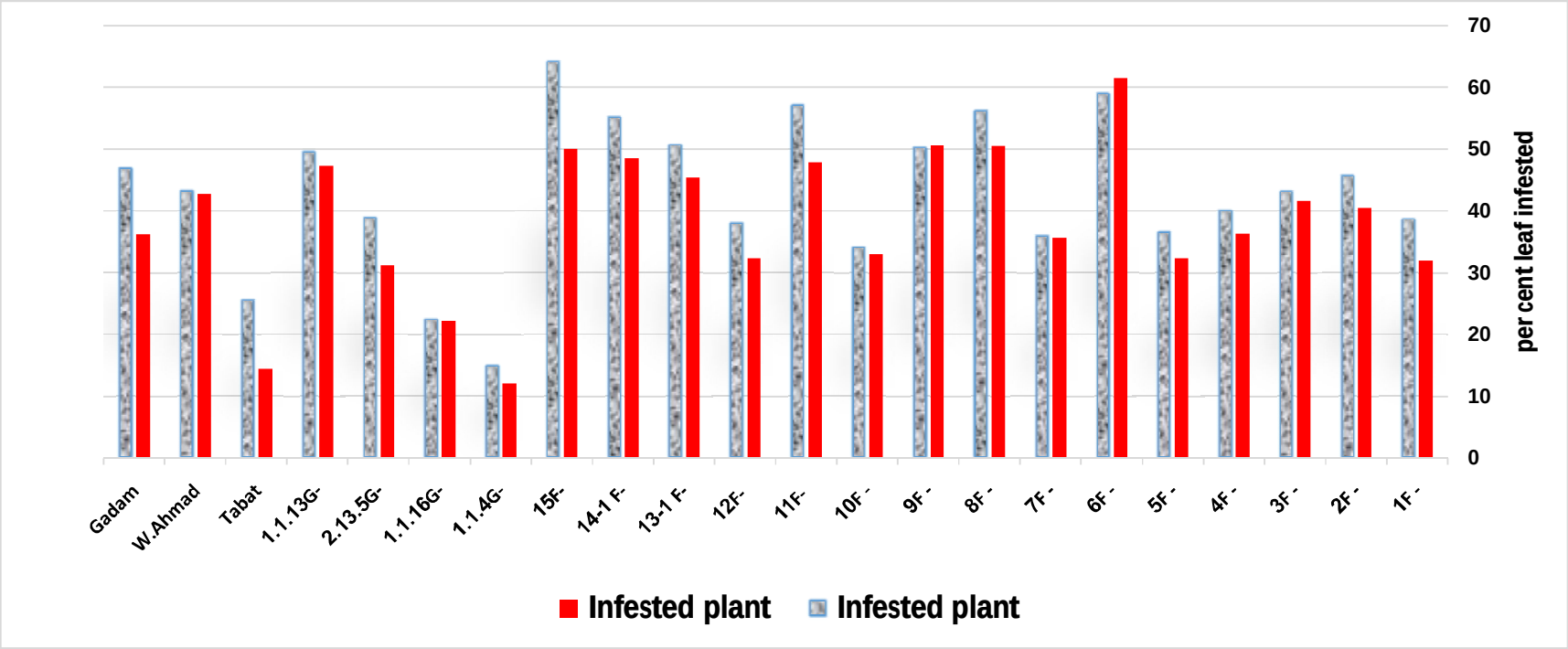

Fig. (4-6): Per cent plant infested by stem borers in different genotypes of Sorghum in (Autumn- Winter) season2016/17

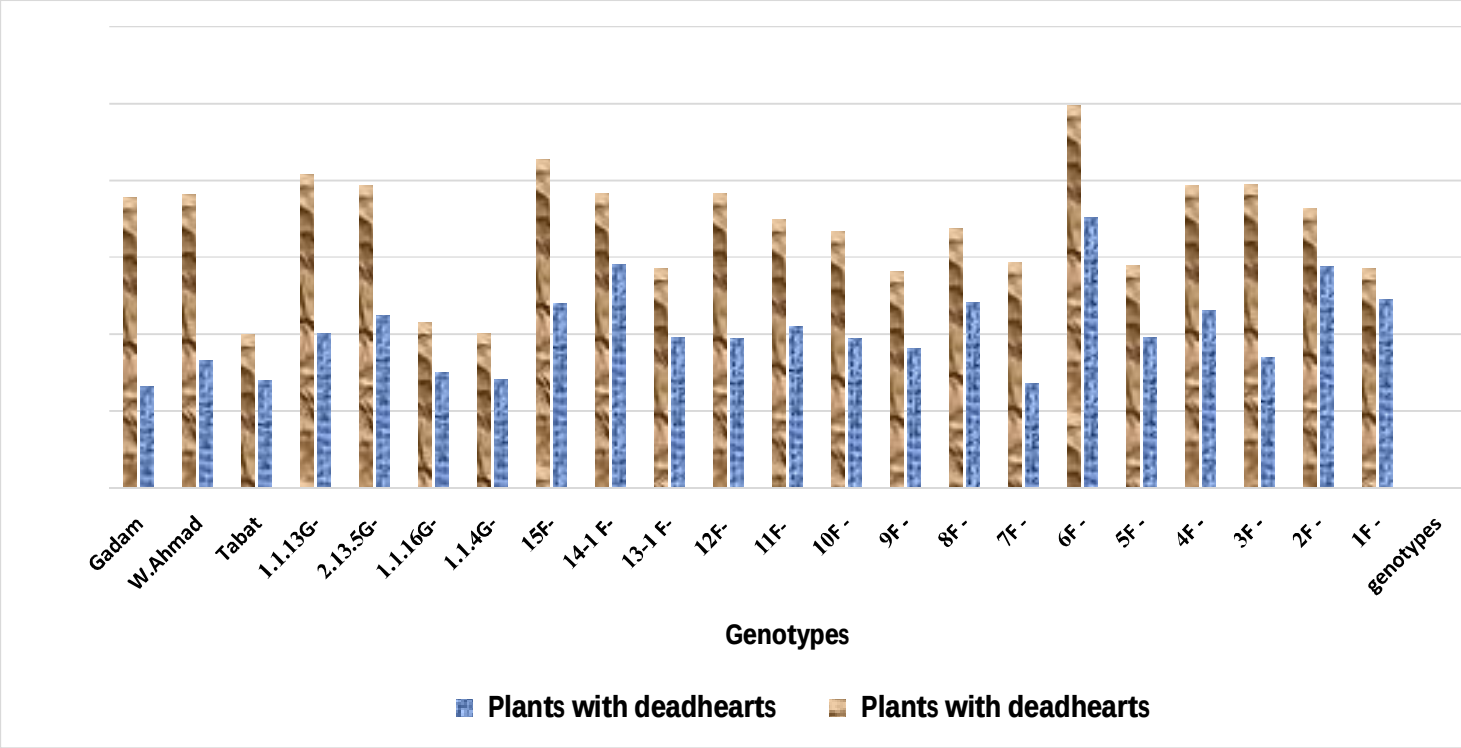

Fig. (4-7) Per cent dead hearts caused by stem borers in different genotypes of Sorghum in (A season2016/17

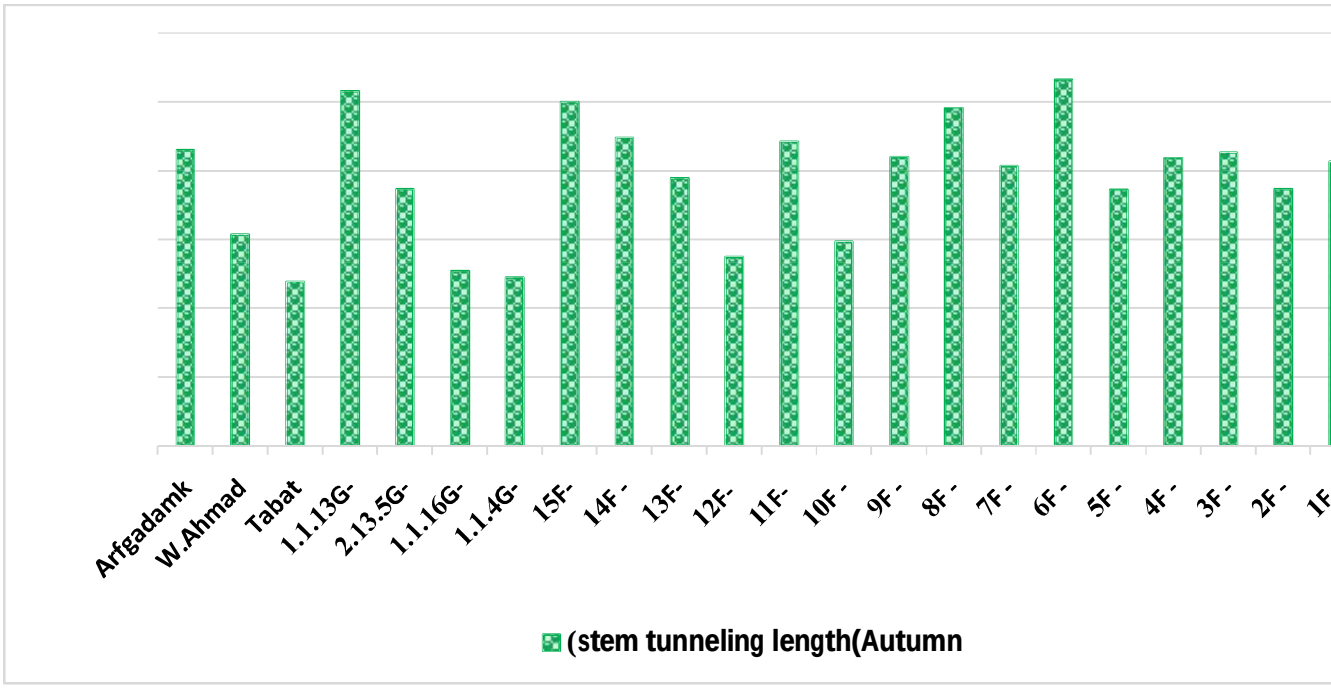

Fig (4-8) Stem tunneling length by stem borers in different genotypes of Sorghum in (Autumn

X axis =genotypes Y axis = Mean value of tunneling length

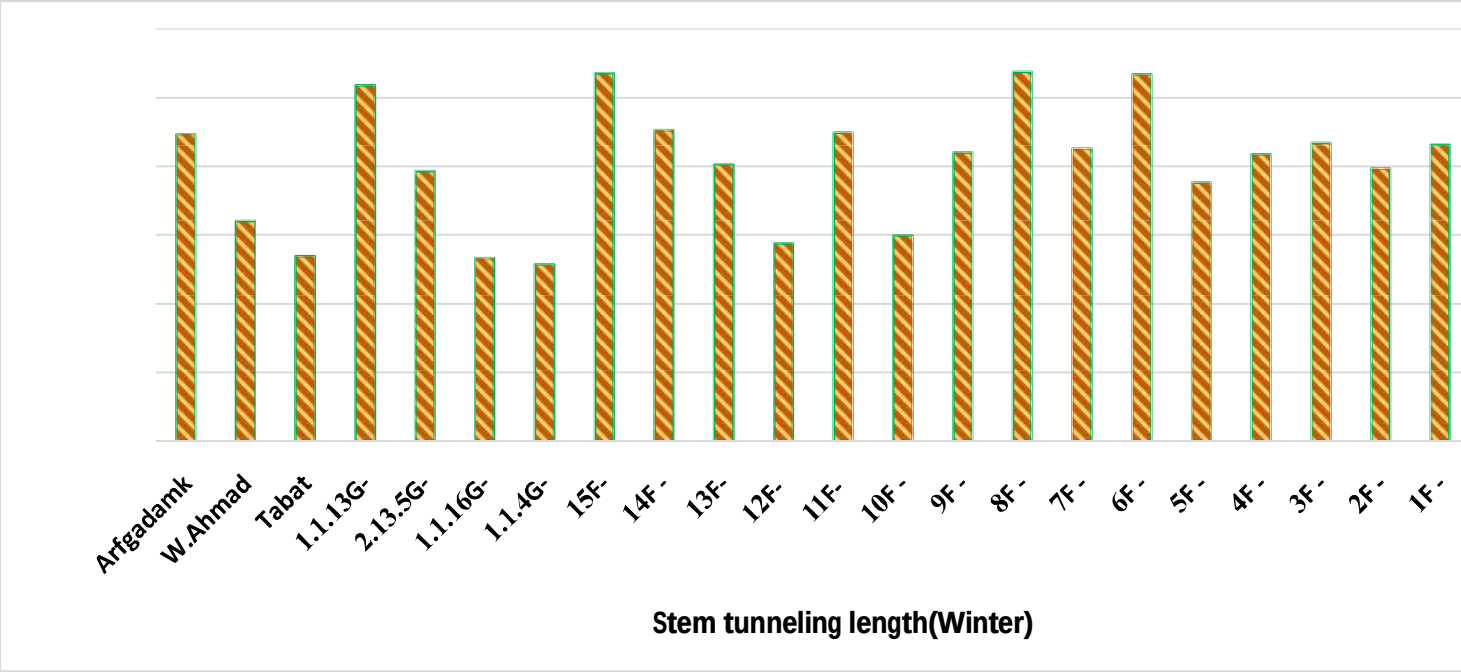

Fig. (4- 9) Stem tunneling length by stem borers in different genotypes of Sorghum in (Winter

X axis =genotypes Y axis = Mean value of tunneling length

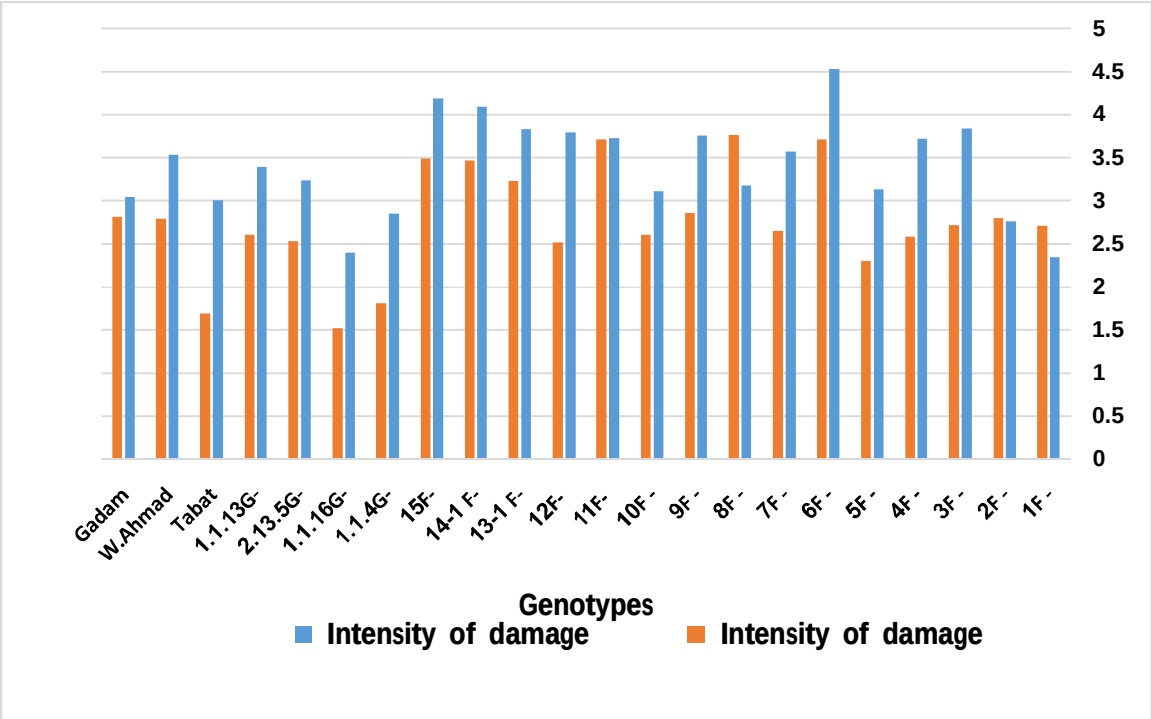

Fig. (4-10): Intensity of damage caused by stem borers in different genotypes of Sorghum in (Autumn – Winter)

Phenotype Variability

4.4 Growth characters

4.4.1 Plant height (cm)

Analysis of variance (ANOVA) showed that there were highly significant differences among the different genotypes in plant height in both seasons (Autumn - Winter). Table 4.13 and appendices10,11,12 and 13. The results of combined analysis showed highly significant differences ($P<0.01$) The means of plant height due to combined results showed that the highest values 197cm and 195cm for the genotype F-5 and F-15 respectively and the lowest values 99cm and 98 were obtained by the genotypes Arfgadamk and W.Ahmed respectively. The overall means for this were (153.19cm) (153.45cm) and the coefficient of variation (CV%) for this character was 4.54% and 8.21% in Autumn and Winter season respectively.Several workers (Naeeim, *et al.,* 2004; Amravati and Buldhana. 2006; Bello, *et al.,* 2007; Alhassan, *et al.,* 2008; Jain *et al.,* 2010; Ayelene, 2011;Mahajan, *et al.*,2011; Warkad, *et al.,* 2011and Puspitasari. *et al.,* 2012;) had also got similar observations and showed significant genetic diversity in plant height in sorghum.

4.4.2 Number of Days to 50% flowering (days)

Statistical analysis of variance showed that there was highly significant difference between sorghum genotypes for number of days to 50% flowering. In Autumn, the highest value (82.3 day) was shown by genotype (F-13) and lowest value (64,3 day) was shown by the genotype (Arfagdamak).While in Winter season the highest value (85 day) was obtained by (F-11) and lowest value (59.6 day) was shown by genotype (Arfagdamak). Coefficient of variation (CV%) for this character was 4.25% and 3.98%) in Autumn and Winter season respectively. The combined result

of the two seasons showed significant in season, and the interaction between all treatments. The means separation due to combined analysis revealed that the highest values (83.3 days) was shown by the genotype F-11, whereas, lowest value (61.95days) was obtained by the genotype (Arfagdamak).Table 4.13 and appendices10,11,12 and 13. These results are in line with the findings of earlier scientists (Naeeim, *et al.*,2004; Amravati and Buldhana 2006, Bello,*et al.*,2007;Alhassan, *et al.*, 2008; Jain, *et al.*, 2010;Ayelene 2011and Mahajan *et al.*,2011;) also observed significant genetic diversity in days to flowering insorghum genotypes.

4.4.3 Number of Days to physiological maturity (days)

Analysis of variance indicated that for the number of days to physiological maturity highly significant difference ($P \leq 0.05$) were detected among genotypes Table 4.14 and appendices 10,11,12 and 13. In Autumn the highest value (122 day) was obtained by genotype (F-13) and lowest value (102 days) was given by the genotype (Arfagdamak).While in Winter season the highest value (125 days) was showwn by (F-11) and lowest value (97 days) was shown by genotype (Arfagdamak). The combined value showed high significance with season, and the interaction between all treatments. The means separation due to combined analysis revealed that the highest values (123.5 days) was shown by the genotype F-11, whereas, lowest value (99.5days) was obtained by the genotype (Arfagdamak).Such types of variability in maturity have also been reported by earlier scientists (Amravati and Buldhana, (2006); Bello,*et al.*,(2007); Jain, *et al.*,(2010), and Mahajan, *et al.*,(2011).

4.4.4 Stem diameter (cm)

Analysis of variance (ANOVA) showed that there were significant differences among the different genotypes in stem diameter at both seasons

(Autumn –Winter) as seen in Table4.15, andappendices 10.11. The mean of highest values (22.37cm and 19.07cm) followed by genotypes (F-5) and (G.1.1.4), while genotypes (F-13) and (G.2.13.5) recorded lowest values (14cm and13.39cm) in Autumn and Winter season respectively. Coefficient of variation (CV%) for this character was 7.44% and 9.66% in Autumn and Winter season respectively.

4.4.5 Number of leaves per plant

Significant differences were detected among the 22 Sorghum genotypes for number of leaves per plant at two seasons (Autumn- Winter) as seen in Table4.14and appendices 10.11. The number of leaves per plant ranged from 9.2 to 15.3 and 8.60 to 13.80 in Autumn and Winter season respectively. The mean of highest values (15.3) (13.80) followed by genotypes (G.1.1.4) and (G.1.1.4) in Autumn and Winter season respectively, while genotypes Arfagdamk and Tabat recorded lowest values (9.2 and 8.60) in Autumn and Winter season respectively. Coefficient of variation (CV%) for this character was 11.46% and 11.7% in Autumn and Winter season respectively. The rest of the lines showed poor performance with the least number of Leaves, Bello *et al.* (2007), Jain *et al.*,(2010) and Puspitasari *et al.*,(2012) reported similar variability in number of leaves per plant in sorghum lines.

Table(4-13): Performance of 22Sorghum genotypesduring two successive seasons (Summer- Winter) 2016/2017

Entry No.	Genotypes	Plant height (cm)			Days to 50% flowering			1000-grain weight(g)			Yield (ton/ha)		
		2016	2017	Combined	2016	2017	Combined	2016	2017	Combined	2016	2017	Combined
1	F -1	181.07^{CD}	183.3^{AB}	182.185	73.3^{DEF}	67.3^{EF}	70.15	38.4^{BCDEF}	36.13^{CD}	37.315	1.27^{ABC}	1.2^{ABC}	1.24
2	F -2	149.6^{HI}	176.3^{ABC}	162.665	80.3^{AB}	82.6^{AB}	81.45	39.5^{ABCDE}	38.6^{BCD}	39.05	1.15^{ABCDE}	1.12^{ABCDEF}	1.135
3	F -3	168.7^{EF}	185^{AB}	176.865	70.3^{EFGH}	64.3^{FG}	67.3	44.8^{AB}	43.2^{AB}	44.00	1.37^{A}	1.35^{A}	136
4	F -4	155^{GH}	190^{A}	172.835	78.3^{ABCD}	81.6^{AB}	79.95	39.4^{ABCDE}	38.7^{BC}	39.05	1.053^{CDEFG}	1.03^{BCDEFG}	1.045
5	F -5	197^{A}	189^{A}	193.165	69.0^{EFGH}	71.6^{CDE}	70.3	35.16^{EF}	34.6^{CDEF}	34.88	1.103^{BCDEF}	1.08^{GH}	1.09
6	F -6	193.6^{AB}	190^{A}	192.17	75.3^{BCDE}	74.3^{B}	74.8	42.7^{ABCD}	42.1^{AB}	42.4	1.343^{AB}	1.28^{AB}	1.31
7	F -7	177.6^{DE}	177^{ABC}	177.5	65.6^{HI}	69.0^{DEF}	67.3	33.8^{EF}	33^{DEF}	33.4	1.050^{CDEFG}	1.02 ^{BCDEFG}	1.035
8	F -8	184.7^{BCD}	186^{A}	185.335	78.3^{ABCD}	70.3^{CDE}	74.3	44.4^{AB}	43.5^{AB}	43.95	1.223^{ABCD}	1.19^{ABC}	1.205
9	F -9	192.3^{ABC}	192^{A}	192.33	73.6^{CDEF}	70.6^{CDE}	72.1	36.6^{DEF}	35.6^{CDE}	36.3	1.216^{ABCD}	1.18^{ABCD}	1.2
10	F -10	161.7^{FG}	164^{BCD}	163	78.6^{ABC}	79.3^{B}	78.95	39.0 ^{ABCDE}	43^{AB}	41	1.043 ^{CDEFG}	1.01^{CDE}	1.025
11	F -11	148.3^{HI}	150DE	149.165	81.6^{A}	85.1^{A}	83.3	36.8^{CDEF}	36^{CDE}	36.45	1.083 ^{BCDEFG}	1.05^{BCD}	1.065
12	F -12	180DE	182^{ABC}	181.165	74.6^{CDE}	73.0^{CD}	73.8	44.8^{AB}	44.2^{AB}	45.65	1.170^{ABCD}	1.14^{ABCDE}	1.155
13	F -1 -13	158^{FGH}	161^{CD}	159.835	82.3^{A}	83.6^{AB}	82.95	31.1^{FG}	30^{EF}	30.6	0.836^{BCDEFG}	0.8^{GH}	0.825
14	F- 1- 14	138.3^{IJ}	139^{EF}	138.83	73.3^{DEF}	73.2^{CD}	73.25	41.0^{ABCDE}	39.7^{ABC}	40.35	0.896^{BCDEFG}	0.86^{FGH}	0.875
15	F -15	187.3^{ABCD}	195^{A}	191.33	81.3^{A}	83.7^{AB}	82.5	43.0^{ABCD}	42^{AB}	42.55	1.050 ^{CDEFG}	1.02 ^{BCDEFG}	1.035
16	G- 1.1.4	121^{KL}	124^{FG}	122.665	67.0^{GHI}	71.6^{CDE}	69.3	46.1^{A}	45^{A}	44.5	1.38^{A}	1.36^{A}	1.37
17	G-1.1.16	113.3^{LM}	115^{GH}	114.33	77.6^{ABCD}	80.3^{AB}	78.95	31.2^{FG}	30.3^{EF}	30.75	0.906^{EFGH}	0.87^{EFGH}	0.885
18	G- 2.13.5	118^{KL}	119^{FGH}	118.5	66.3^{HI}	74.1^{C}	70.15	43.1^{ABCD}	42^{AB}	42.6	0.956^{DEFGH}	0.92^{DEFGH}	0.9415
19	G- 1.1.13	113^{LM}	117^{GH}	115.335	71.6^{EFG}	69.6^{DEF}	70.6	46.0^{A}	44.9^{A}	45.5	1.086 ^{BCDEFG}	1.05 ^{BCDEFG}	1.065
20	Tabat	104.6$_{MN}$	100^{H}	102.67	72.3^{EF}	68.6^{DEF}	70.45	44.1^{ABC}	43^{AB}	43.55	^{BCDEF} 1.086	1.05^{BCDEFG}	1.065
21	W.Ahmad	128^{JK}	98^{H}	113.33	69.0^{FGHI}	72.6^{CD}	70.8	31.1^{FG}	30.3^{EF}	30.8	0.996^{DEFGH}	0.96^{CDEFGH}	0.985
22	Arfagadamk	99^{N}	102^{H}	100.835	64.3^{I}	59.6^{G}	61.95	23.9^{G}	23.2^{G}	23.55	0.763$_{H}$	0.74^{H}	0.75
C.V		4.54	8.21	6.7	4.25	3.98	4.11	11.44	9.05	10.4	14.89	15.21	15.00
LSD		11.449	21.153	17.33	5.153	4.8410	5.066	7.337	5.711	6.79	0.2680	0.2663	0.270

The mean with the same later in coloum was not significant according to Duncan Multiple Range Test

4.4.6Leaf area (cm^2)

The results showed that, highly significant difference of leaf area among genotypes. In Autumn season genotype (F-4) resulted 527 cm this is regard highest value while genotype (F-15) resulted lowest value(336cm). However, in Winter season genotype (F-4) resulted 520.3cm this is regard highest value while genotype (W.Ahmed) resulted lowest value (226.6cm). Coefficient of variation (CV%) for this character was (7.81% and 4.75%) in Autumn and Winter season respectively. Table 4.15and appendices 10.11The results of Naim *et al.*,(2012) contradicted our findings which may be due to difference in environmental conditions and genotypes used.

4.4.7 Head excretion (cm)

The results showed that significant differences were detected among genotypes for head excretion as seen in Table4.16 and appendices 10,11. The highest value of head excretion (26cm and 29 cm) were shown by the genotypes (F-8 and F-3),and the lowest values (19 cm and 17cm) was obtained by the genotypes (F-6 and F-10) in Autumn and Winter season respectively. The coefficient of variation (CV%) for this character was (15.15% and 6.78%) in Autumn and Winter season respectively.

Table (4-14) Means of some growth and yield traits of 22 Sorghumgenotypes at Shambat Season 2016-17

	Days to physiological maturity		Number of Leaves/plant	
Var. Name	**Autumn**	**Winter**	**Autumn**	**Winter**
F -1	111^{DEF}	107^{EFG}	14.13^{ABC}	12.4^{ABC}
F -2	121^{AB}	122^{AB}	13.33^{ABC}	12.1^{ABC}
F -3	110^{DEFG}	102^{GH}	13.06^{ABC}	11.96^{ABC}
F -4	118^{AB}	122^{AB}	13.93^{ABC}	11.73^{ABCD}
F -5	107^{EFGH}	109^{DEF}	14.40^{ABC}	13.8^{A}
F -6	112^{CDE}	113^{CD}	12.60^{BCD}	12.13^{ABC}
F -7	104^{H}	107^{EFG}	14.60^{AB}	11.6^{ABCD}
F -8	118^{AB}	110^{DEF}	13.33^{ABC}	11.8^{ABC}
F -9	113^{CD}	110^{DEF}	12.73^{BCD}	12.9^{AB}
F -10	118^{AB}	118^{BC}	14.66^{AB}	12.4^{ABC}
F-11	122^{A}	125^{A}	12.06^{CDE}	10.1^{CDEF}
F- 12	116^{BC}	112^{DE}	14.00^{ABC}	11.2^{BCDE}
F -13	122^{A}	122^{AB}	14.00^{ABC}	11.7^{ABCD}
F-14	111^{DEF}	113^{CD}	14.40^{ABC}	13.1^{AB}
F-15	119^{AB}	122^{AB}	13.46^{ABC}	10.4^{CDEF}
G-1.1.4	105^{GH}	109DEF	15.33^{A}	13.3^{A}
G-1.1.16	116^{BC}	120^{AB}	10.60^{EF}	9.5^{DEF}
G-2.13.5	105^{GH}	109^{DEF}	9.86^{EF}	11^{BCDE}
G-1.1.13	110^{DEFG}	105^{FG}	9.80^{EF}	10.6^{CDEF}
Tabat	109^{DEFG}	106^{FG}	10.06^{DEF}	8.6^{F}
W.Ahmad	107^{EFGH}	109^{DEF}	9.60^{F}	9.4^{EF}
Arfgadamk	102^{H}	97^{H}	9.20^{F}	9.4^{EF}
CV%	**2.85**	**2.89**	**11.34**	**11.7**
SE±	**1.85**	**1.878**	**1.174**	**1.0926**
LSD(0.05)	**3.3038**	**5.36**	**2.3691**	**2.2051**

The mean with the same later in later in coloum was not significant according to Duncan Multiple Range Test (DMRT).

Table (4-15) Means of some growth and yield traits of 22 Sorghumgenotypes at Shambat Season 2016-17

	Stem diameter		Leaf Area	
Var. Name	**Autumn**	**Winter**	**Autumn**	**Winter**
F -1	13.7^{EFG}	21.58^{AB}	386^{HIJK}	442^{BCDE}
F -2	14.8^{DEFG}	17.22^{FGH}	396^{GHIJ}	441^{BCDE}
F -3	15.7^{CDEFG}	19.80^{BCD}	391.67^{HIJK}	404^{EFG}
F -4	16.2^{BCD}	16.60^{GHI}	520.33^{A}	527^{A}
F -5	16.4^{BCD}	22.37^{A}	407.33^{GHI}	413^{EFG}
F -6	15.23^{DEFG}	20.12^{BC}	452.67^{DEF}	450^{BCDE}
F -7	14.9^{DEFG}	19.06^{BCD}	486^{BC}	497^{AB}
F -8	15.8^{CDEF}	19.60^{BCD}	484^{BCD}	486^{ABC}
F -9	15.5^{CDEFG}	14.96	426.67^{FG}	380^{FGH}
F -10	16.41^{BCD}	18.21^{CDEFG}	424.33^{FG}	440^{CDE}
F-11	13.4^{FG}	13.17^{K}	377^{IJKL}	376^{FGH}
F- 12	15.3^{DEFG}	17.82^{DEFGH}	447.67^{EF}	459^{BCDE}
F -13	18.3^{AB}	14.00^{JK}	502.67^{AB}	527^{A}
F-14	14.8^{DEFG}	17.05^{FGHI}	413^{GH}	420^{DEF}
F-15	14.07^{DEFG}	19.42^{BCDE}	362.67^{KL}	336^{H}
G-1.1.4	19.03^{A}	20.20^{ABC}	459.33^{CDE}	469^{BCD}
G-1.1.16	17.8^{ABC}	19.97^{BCD}	370.67^{JKL}	409^{EFG}
G-2.13.5	13.3^{G}	14.12^{JK}	456^{CDEF}	455^{BCDE}
G-1.1.13	16.01^{BCDE}	15.76^{HIJ}	414.67^{GH}	372^{FGH}
Tabat	15.48^{CDEFG}	16.49^{GHI}	280.67^{M}	422^{DEF}
W.Ahmad	14.23^{BEFG}	17.36^{EFGH}	226.67^{N}	365^{GH}
Arfgadamk	15.04^{DEFG}	16.47^{GHI}	347.33^{L}	377^{FGH}
CV%	**9.65**	**7.44**	**4.75**	**7.81**
SE±	**1.2280**	**1.0810**	**15.909**	**27.4**
LSD(0.05)	**2.478**	**2.1816**	**32.106**	**55.40**

The mean with the same later in later in coloum was not significant according to Duncan Multiple Range Test (DMRT).

4.5 Grain yield characters

4.5.1 Panicle length (cm)

Analysis of variance reflected highly significant difference among the 22 sorghum genotypes in panicle length. The means of this character ranged between (14.3 to 29 cm) and (14 to 26cm), in Autumn and Winter season respectively. In Autumn the highest value (29cm) was obtained by genotype (F-10) and lowest value (14.3 cm) was shown by the genotype (G.2.13.5). While in Winter season the highest value (26cm) was obtained by (F-10) and lowest value (14cm) was shown by genotype (G.2.13.5). The overall means for this was (19.17) (18.72cm) and the coefficient of variation (CV%)was (2.05cm) (7.51) in Autumn and Winter season respectively,as seen in Table 4.16 and appendices 10,11.

4.5.2 Panicle width (cm)

Analysis of variance reflected significant difference among the sorghum genotypes in head width as seen in Table 4.16 and appendices 10,11. The range in panicle width in Autumn season was from 9.66cm for W.Ahmad to 16 cm for F-2. While range in panicle width in Winter season from 9 cm for W. Ahmad, Arfagdamak to 16 cm for F-2. Coefficient of variation (CV%) for this character was (9.59 % and 10.34%) in Autumn and Winter season respectively.

Table (4.16) Means of some Genotypes on Panicle Weight and Panicle length and Panicle exsertion of Sorghum

	Panicle Length		Panicle Width		HeadExcretion	
Var. Name	**Winter**	**Autumn**	**Winter**	**Autumn**	**Winter**	**Autumn**
F -1	18^{EFG}	16.33^{IJ}	10^{EF}	12^{EFGH}	30.3^{A}	24.6^{AB}
F -2	16^{GH}	19.33^{EF}	9^{F}	16^{AB}	23.3^{CDE}	$24.3A^{BC}$
F -3	19.3^{DEF}	19.66^{DE}	14^{B}	13.6^{CDE}	29.0^{A}	22.6^{ABC}
F -4	17.3^{FG}	17.66^{GH}	10^{EF}	12^{EFGH}	26.3^{B}	24^{ABC}
F -5	22^{BC}	15.66^{JK}	12^{CD}	11^{GHI}	21.0^{EF}	24^{ABC}
F -6	24^{AB}	23.33^{B}	16^{A}	15^{ABC}	23.0^{CDE}	19^{C}
F -7	18.6^{DEF}	18.33^{FG}	14^{B}	13^{DEF}	24.0^{BCD}	19^{C}
F -8	15.3^{H}	15^{JK}	10^{EF}	11^{GHI}	18.0^{GH}	26^{A}
F -9	22.6^{BC}	23^{B}	12^{CD}	11.33	25.0^{BC}	20^{BC}
F -10	26^{A}	29^{A}	11^{DE}	14.33^{BCD}	17.0^{H}	22^{ABC}
F-11	17^{FG}	17.66^{GH}	12^{CD}	14^{CD}	26.0^{B}	19^{C}
F- 12	19.3^{DEF}	20^{DE}	14^{B}	14^{CD}	22.0^{CDE}	24^{AB}
F -13	20.3^{CDE}	20.66^{CD}	11^{DE}	12.66^{CDE}	18.0^{GH}	20^{BC}
F-14	17.3^{FG}	17.66^{GH}	10^{EF}	11.66^{FGH}	21.0^{EF}	23.3^{ABC}
F-15	20^{CDE}	19.66^{DE}	12^{CD}	11.66^{FGH}	23.0^{CDE}	24.3^{ABC}
G-1.1.4	22.3^{BC}	22.66^{B}	14^{B}	16.33^{A}	22.0^{DEF}	24^{ABC}
G-1.1.16	16.6^{FG}	17^{HI}	13^{BC}	12^{EFGH}	22.0^{DEF}	21.6^{ABC}
G-2.13.5	14.6^{H}	14.33^{L}	10^{EF}	11^{GHI}	23.3^{CDE}	23.3^{ABC}
G-1.1.13	21.3^{CD}	21.33^{C}	16^{A}	14.33^{BCD}	23.0^{CDE}	22.3^{ABC}
Tabat	16.3^{GH}	16^{IJK}	11^{DE}	10.33^{HI}	20^{FG}	23^{ABC}
W.Ahmad	17.3^{FG}	18^{GH}	9^{F}	9.66^{I}	22.6^{CDEF}	21^{ABC}
Arfgadamk	17^{FG}	19.66^{DE}	9^{F}	10.33^{HI}	21.3^{EF}	22^{ABC}
CV%	**7.51**	**3.81**	**9.59**	**9.09**	**6.78**	**15.15**
SE±	**1.1491**	**0.397**	**0.9219**	**0.9354**	**1.2658**	**2.78**
LSD(0.05)	**2.3189**	**1.2048**	**1.86**	**1.8877**	**2.55**	**5.3375**

The mean with the same later in later in coloum was not significant according to Duncan Multiple Range Test (DMRT).

4.5.3 Thousand -seed weight (g)

Analysis of variance reflected highly significant difference among the 22 sorghum genotypes in 1000 seed weight.The means separation due to combined analysis revealed that the highest values (45.6g) was shown by the genotype F-12, whereas, lowest value (23.6) was obtained by the genotype (Arfagdamak) as seen in Table4.13 and appendices 10,11.

4.5.4 Grain yield (Ton/ha)

The analysis of variance showed, highly significant differences were shown for the 22 sorghum genotypes for grain yield ton/ha in as seen in Table 4.13 and appendixces 10.11. The highest value (1.38 t/ha, 1.37 t/ha) (1.37 t/ha, 1.36 t/ha) were given by genotypes (G.1.1.4) (F-3). And the lowest value (0.76 t/ha and 0.74 t/ha) in Autumn and Winter season respectively.The means separation due to combined analysis revealed that the highest values (45.6g) was shown by the genotype F-11, whereas, lowest value (23.6) was obtained by the genotype (Arfagdamak). The highest range of genetic variabilityin grain yield of sorghum genotypes similar to this study was also reported byearlier scientist (Naeeim *et al.*,(2004); Amravati and Buldhana, (2006); Jain *et al*., (2010); Mahajan*et al.*,(2011) and Naim *et al.*,(2012)

4.6 Estimates of variability

The ranges, means and coefficients of variation for the characters studied are summarized in Tables 17, 18. There was a wide range of variation in most of the characters. The coefficient of variation ranged from (2.05% to 20.72% and2.89% to 29.07%) in Autumn and Winter, respectively. The estimates of the phenotypic, genotypic, and environmental components of variance for the different characters are presented in Tables 19, 20. The phenotypic component of variance ranged from 0.05 and 0.04for grain yield/t/ha to 3444.38 and 5045.60 for leaf areafor plant height. Relatively high components of phenotypic variance were observed for leaf area, plant weight and plant height. On the other hand, panicle width, panicle length stem diameter and number of leaves had relatively low values of phenotypic variance. The genotypic variance ranged from 0.020 and 0.017 for grain yield/t/ha to 2313.703 and 4665.9 for leaf area. Plant height, days to 50% flowering, and 1000-seed weight had relatively high values of genotypic variances. Low values of genotypic variance were recorded for head length, head width and number of leaves per plant. For all characters studied, the environmental variance was less than the genotypic component. The genetic coefficient of variation (GCV) ranged from 1.47% for PE to 24.24% for GY and 6.36 %for DM to 24.54% for GYas seen in Tables 21, 22. High values of (GCV) were recorded for GY, PH, and PL.

4.6.1 Estimates of Phenotypic (δ^2ph) and genotypic (δ^2g) variance and Heritability (h^2) among sorghum genotypes

The estimates of the phenotypic, genotypic and environmental components of variation for the different characters are presented in Tables 4.19 and 4.20. The results of this study for two seasons (Autumn & Winter) height estimates of the genotypic variances (σ^2g) 2313.703 and 4665.9 were scored by leaf area. Whereas, the lowest estimates of genotypic for the seasons 0.020 and 0.017 were attended by grain yield (ton/ha). On the other hand, height estimates of phenotypic variance (σ^2ph) (3444.38 and 5045.60) (1047.98 and 1327.47) regarded by leaf area and plant height. whereas, the lowest values (0.05 and

0.04) (0.80 and 0.79) obtained by Grain yield (t/ha) for two seasons. Regarding heritability estimates, the values characters were greater at Autumn season than the Winter season for all characters expect Leaf area, Days to 50%flowering, Days to 95% maturity, panicle width and 1000gweight. The high value of heritability (h^2) were revealed for plant height for two seasons. The highest heritability estimates (0.95% - 0.88%) were recorded by Plant heightand the lowest estimates of heritability (h^2=0.43 ,0.41%) were given by grain yield (ton/ha).

4.6.2 Estimates of Phenotypic (PCV) and genotypic (GCV) coefficient of variation traits

Estimates of genotypic coefficient of variation (GCV) in Autumn season, highest value 24.24 wasobtained by Grain yield t/ha, and also in Winter Season Grain yield t/ha showed highest 24.45. On the other hand, the lowest value (5.26) in Autumn regarded by days to 95% maturity, and also in Winter season days to 95% maturity showed lowest value (6.36). Tables 4.21 and 4.22. On the other hand, (PCV) regarding high values (28.45), (28.87) by Grain yield in Autumn and Winter, respectively. Whereas, lowest value (5.99), (6.36) revealed by days to 95% maturity in Autumn and Winter, respectively.

4.6.3 Heritability

Heritability in the broad sense ranged from 41% for grain yield to 95% for plant height as seen in Tables 4.21, and 4.22.

In present studies most of the traits showed higher estimates of broad sense heritability. The characters including, , plant height, leaf area , days to 50% flowering, days to maturity and 1000 grain weight, exhibited very high heritability suggesting that simple selection would be sufficient for these traits for genetic improvement of desirable traits. But Johnson *et. al.* (1955) suggested that heritability values alone may not provide clear predictability of selection made.

Table 4-17: Phenotypic variability in 16 characters of 22 Sorghum genotypes in Autumn season at Shambat, 2017

Number	Characters	Range	Mean	C.V.%
1	Plant height (cm)	197 – 99	153.19	4.54
2	Stem diameter (cm)	22.37 – 14	17.77	7.44
3	Number of leaves/plant	15.3 - 9.2	12.6	11.46
4	Leaf Area	527 – 336	430	7.81
5	Days to 50% flowering	82.3 - 64.3	73.8	4.25
6	Days to Maturity	122 - 107	112.5	2.85
7	Panicle width (cm)	16 - 9	13.16	10.34
8	Panicle length(cm)	26 – 14	18.95	2.05
9	Plant dry weight (g)	230.3 – 127.3	182.1	14.8
10	1000 – seed weight	45.20 - 23.3	38.94	11.44
11	Yield (ton/ha)	1.37 - 0.74	1.092	14.89
12	Infested Plant(IP %) 20DAS	6.5 - 0.22	4.37	17.56
13	Infested Plant(IP %) 40DAS	8.05 - 3.5	6.13	6.68
14	Infested Plant(IP%) 60 DAS	9 - 4.87	7.32	4.29
15	Dead Hearts (DH %)	17.60 - 6.60	2.96	20.72
16	Intensity of Damage(ID)	4.53 - 2.34	3.46	21.94

Table 4-18: Phenotypic variability in 16 characters of 22 Sorghum genotypes in Winter season at Shambat, 2016/2017

Number	Characters	Range	Mean	C.V.%
1	Plant height (cm)	195 – 98	153.45	8.21
2	Stem diameter (cm)	19.07 – 13.39	15.56	9.66
3	Number of leaves	13.80 - 8.60	11.44	11.7
4	Leaf Area	520.3 – 226	410	4.75
5	Days to 50% flowering	85 - 59.6	73.8	3.98
6	Days to Maturity	125 - 97	112.1	2.89
7	Panicle width (cm)	16 - 9	11.77	9.59
8	Panicle length(cm)	26 – 14	18.72	7.51
9	Plant dry weight (g)	226.3 – 124.4	177	15.23
10	1000 – seed weight	45.20 - 23.3	38.29	9.05
11	Yield (ton/ha)	1.37 - 0.74	1.067	15.21
12	Infested Plant(IP %) 20DAS	6.69 - 1.26	5.119	13.72
13	Infested Plant(IP %) 40DAS	8.51 - 3.73	6.45	7.93
14	Infested Plant(IP%) 60 DAS	8.82 - 5.21	7.59	4.49
15	Dead Hearts (DH %)	24.9 - 10	2.9	29.07
16	Intensity of Damage(ID)	3.77 - 1.52	2.77	6.51

Table 4.19 Phenotypic (σ^2ph) and Genotypic(σ^2g) and environmental (σ^2e) variances for different characters in Sorghum genotypes at (Autumn) season2016-17

Characters	σ^2g	σ^2ph	σ^2e
Plant height(cm)	999.6367	1047.93	48.29
Stem diameter(cm)	5.6208	7.37	1.75
Number of leaves/plant	2.9978	5.07	2.07
Leaf Area(cm)	2313.703	3444.38	1130.68
Days to 50%Flowering	27.18253	37.05	9.87
Days to 50%Maturity	34.63767	45.00	10.36
Panicle Length	11.28117	11.82	0.53
Panicle width	3.061333	4.37	1.31
Plant dry weight (g)	523.24	1258.3	735
Head excretion	0.059167	11.68	11.62
1000 Grain Weight	29.59	49.59	20.00
Grain yield(Ton/ha)	0.020167	0.05	0.03
Infested plant	141.68	154.23	12.54
Dead hearts	0.14	0.44	0.29
Stem tunneling	0.76	0.80	0.04

Table 4.20 Phenotypic (σ^2ph) and Genotypic(σ^2g) and environmental (σ^2e) variances for different characters in Sorghum genotypes at (Winter) season2016-17

Characters	σ^2g	σ^2ph	σ^2e
Plant height(cm)	1162.66	1327.46	164.8
Stem diameter(cm)	1.41508	3.67	2.26
Number of leaf/plant	1.314277	3.11	1.79
Leaf Area(cm)	4665.9	5045.60	379.70
Days to 50%Flowering	43.74467	52.38	8.63
Days to 50%Maturity	51.21867	61.80	10.58
Panicle Length	9.071433	11.05	1.98
Panicle width	4.2352	5.51	1.27
Plant dry weight (g)	498.6	1226.13	727.5
Head excretion	9.511567	11.91	2.40
1000 Grain Weight	32.70133	44.71	12.013
Grain yield(Ton/ha)	0.017997	0.04	0.03
Infested plant	145.55	161.96	16.734
Dead hearts	0.34	0.52	0.71423
Stem tunneling	0.79	0.79	0.00831

Table (4.21): Estimates of heritability in the broad sense (h^{2B}) genotypic and phenotypic coefficients of variation and for 22 sorghum genotyped growing at Shambat in Autumn season 2016-17

Traits	Range	Mean	$\sigma^2 g$	$\sigma^2 ph$	GCV	PCV	h^2
Infested plant	61.59 – 12.18	38.43	141.68	154.23	30.97	32.31	91.86
Dead heart	24.9 – 9.7	17.026	0.14	0.44	13.78	22.16	31.59
Tunnels length (cm)	28.28 – 5.61	15.85	0.76	0.80	5.29	5.42	94.96
Plant height(cm)	197 – 99	153.19	999.6367	1047.93	20.64	21.13	95.39
Stem diameter(cm)	22.37 – 14	17.77	5.6208	7.37	13.38	15.31	76.23
Number of leaf/plant	15.3 - 9.2	12.6	2.9978	5.07	13.86	17.95	59.19
Leaf Area(cm)	527 – 336	430	2313.703	3444.38	11.17	13.63	67.17
Days to 50%Flowering	82.3 - 64.3	73.8	27.18253	37.05	7.07	8.25	73.36
Days to 50%Maturity	122 - 102	112.5	34.63767	45.00	5.26	5.99	76.97
Plant dry weight (g)	230.3 – 127.3	182.1	523.24	1258.3	12.56	19.48	41.58
Panicle Length	16.33 - 9.66	13.16	11.28117	11.82	17.53	17.94	95.48
Panicle width	29 – 14.3	18.95	3.061333	4.37	13.99	16.68	69.99
Head excretion	26 - 19	22.5	0.059167	11.68	1.47	15.22	0.51
1000 seeds weight	46.1 - 23.9	38.94	29.59233	49.59	13.98	18.09	59.68
Grain yield(Ton/ha)	1.38 - 0.76	1.092	0.020167	0.05	24.24	28.45	43.25

Table (4.22) Estimates of heritability in the broad sense (h^{2B}) genotypic and phenotyp variation for 22 sorghum genotyped growing at Shambat in Winter season

Traits	Range	Mean	$\sigma^2 g$	$\sigma^2 ph$	GCV
Infested plant	59.15 – 15.12	43.16	161.96	145.55	27.93
Dead heart	21.3 – 8.4	13.65	0.52	0.34	15.64
Tunnels length (cm)	28.86	16.97	0.79	0.79	5.39
Plant height(cm)	195 – 98	153.45	1162.66	1327.46	21.80
Stem diameter(cm)	19.07 – 13.39	15.56	1.41508	3.67	7.78
Number of leaf/plant	13.80 - 8.60	11.44	1.314277	3.11	10.21
Leaf Area(cm)	520.3 – 226	410	4665.9	5045.60	16.66
Days to 50%Flowering	85 - 59.6	73.8	43.74467	52.38	8.96
Days to 50%Maturity	125 - 97	112.1	51.21867	61.80	6.36
Plant dry weight (g)	226.3 -124.4	177	498.6	1226.13	12.62
Panicle Length	16 - 9	11.77	9.071433	11.05	16.13
Panicle width	26 – 14	18.72	4.2352	5.51	17.58
Head excretion	29 - 17	22.87	9.511567	11.91	13.52
1000 seeds weight	45.20 - 23.2	38.29	32.70133	44.71	14.95
Grain yield(Ton/ha)	1.36 - 0.74	1.067	28.87	24.54	24.54

Table(4-23): Phenotypic (σ^2ph) and Genotypic(σ^2g) variances and Heritability h2 for diffe in (Autumn & Winter) season (2016/2017)

Parameter	Genotypic Variance σ^2g Autumn	Genotypic Variance σ^2g Winter	Phenotypic Variance σ^2ph Autumn	Phenotypic Variance σ^2ph Winter	Heritability (%) Autumn	Heri (W
nt height(cm)	999.6367	1162.66	1047.93	1327.46	0.95	0
em diameter(cm)	5.6208	1.41508	7.37	3.67	0.76	0
mber of leaves per plant	2.9978	1.314277	5.07	3.11	0.59	0
af Area(cm)	2313.703	4665.9	3444.38	5045.60	0.67	0
ys to 50%Flowering	27.18253	43.74467	37.05	52.38	0.73	0
ys to 50%Maturity	34.63767	51.21867	45.00	61.80	0.77	0
ant dry weight (g)	523.24	498.6	1258.3	1226.13	0.42	0
nicle Length(cm)	11.28117	9.071433	11.82	11.05	0.95	0
nicle width(cm)	3.061333	4.2352	4.37	5.51	0.70	0
nicle Exsetion(cm)	0.059167	9.511567	11.68	11.91	0.01	0
00 seeds weight	29.59233	32.70133	49.59	44.71	0.60	0
ain yield(ton/ha)	0.020167	0.017997	0.05	0.04	0.43	0

GCV% = genotypic coefficient of variation, PCV% = phenotypic coefficient of variation, H_2 %= broad sense heritability, GAM = genetic advance as % of me days to 50% flowering, NT/P = number of harvestable tillers, PL (cm) = panicle length (cm), PW (cm) = panicle width (cm), DPW (g) = dry panicle weight, SM ($_1$) = grain yield.

4.7 Phenotypic correlations between different traits:

The result of phenotypic correlation coefficient between some growth, yield and stem borers infestation for the different characters in each season are presented in Tables 4.18 and 4.19.In Autumn, the results showed that highly significant positive correlated with Days to flowering was positively and significant correlated with days to maturity (r=0.944), and negatively correlated with stem diameter (r=-0.215),while positively correlated with infested plant(r=0.305), dead hearts (r=0.267) and stem tunneling(r=0.144).Plant height showed positive and significant correlation with number of leaves/plant (r=0.604), infested plant (r=466),stem diameter(r=0.379) stem tunneling (r= 0.369) grain yield (r=0.364) and dead hearts (r=0.333).Stem diameter was positively and significantly correlated with number of leaves/plant (r=369), Head exrsetion (r=0.227) grain yield (r=0.225), but negatively correlated with days to maturity (r= -0.215). Stem tunneling was positively correlated with infested plant (r= 0.794) dead heart(r=0.428), plant height(r=369), but negatively correlated with stem diameter (r= -0.079). Table (4.18). In Winter season, the results showed that highly significant positive correlated with Days to flowering was positively and significant correlated with days to maturity (r=0.966), and negatively correlated with stem diameter (r=-0.146), panicle ex (r= -0.124), panicle width (r= -0.090) and stem tunneling (r= -0.054). Stem tunneling was positively correlated with infested plant (r= 0.827), leaf area (r=0.449), plant height (r=0.408) dead heart (r=0.402), number of leaves/plant (r=0.354) and plant height(r=369), but negatively correlated with days to 50% flowering (r= -0.054), panicle length (r= -0.024) while infested plant positively correlated with stem tunneling (r=0.827), dead hearts (r=0.420). but negatively correlated with stem diameter (r= -0.111), panicle length(r=-

0.059),1000gain weight (r=-0.053) and grain yield (r= -0.051). Plant height showed positively and significant correlated with leaf area (r=0.643), number of leaves/plant (r=0.633), stem tunneling (r=0.408)infested plant (r=373), grain yield (r=0.334) panicle length(r=0.282).days to maturity (r=0.275) and dead hearts (r=0.181).Stem diameter was positively and significant correlated with number of leaves/plant (r=0.166), Head exrsetion (r=0.125), but negative correlated with dead heart(r= -0.112), infested plant (r= -0.111) and 1000grain weight (r= -0.045). as seen in Table 4.19.

Table(4.24): Phenotypic Correlation between morphological and damage parameters at (Autumn season)

	PH	*SD*	*No.L/P*	*L A*	*DF*	*DM*	*YG*	*1000GW*	*PL*	*PW*	*PE*	*IP*	*DH*	*ST*
PH	**1.000**													
SD	**0.379**	**1.000**												
No.L/P	**0.604***	**0.369***	**1.000**											
L A	**0.347**	**-0.010**	**0.386***	**1.000**										
DF	**0.304**	**-0.184**	**0.240**	**0.348**	**1.000**									
DM	**0.289**	**-0.215**	**0.295**	**0.353***	**0.944***	**1.000**								
YG	**0.364***	**0.225**	**0.132**	**-0.110**	**0.027**	**0.015**	**1.000**							
1000GW	**0.134**	**0.103**	**0.183**	**-0.001**	**0.047**	**0.091**	**0.433***	**1.000**						
PL	**0.134**	**-0.056**	**0.112**	**-0.152**	**0.164**	**0.141**	**0.167**	**-0.004**	**1.000**					
PW	**0.095**	**0.077**	**0.239**	**-0.052**	**0.230**	**0.274**	**0.317**	**0.238**	**0.476***	**1.000**				
PE	**0.002**	**0.227**	**0.068**	**0.160**	**0.138**	**0.126**	**0.173**	**0.277**	**-0.181**	**0.007**	**1.000**			
IP	**0.466***	**-0.186**	**0.059**	**0.160**	**0.356**	**0.305**	**0.078**	**-0.005**	**0.173**	**0.032**	**-0.109**	**1.000**		
DH	**0.333**	**0.054**	**0.215**	**0.143**	**0.267**	**0.252**	**0.202**	**0.189**	**0.078**	**0.171**	**0.044**	**0.468***	**1.000**	
ST	**0.369***	**-0.079**	**0.123**	**0.186**	**0.144**	**0.102**	**0.094**	**0.041**	**-0.007**	**-0.013**	**-0.103**	**0.794***	**0.428***	**1.000**

*.** =Correlation is significant , Highly Significant

PH =Plant height**,SD=** Stem diameter**,No.L/p =** Number of leaves /plant**,LA =** Leaf Area **, DF =** Days to 50% flowering **, DM =** Days to 95 % maturity **,PL =** Panicle length **,PW=** Panicle width **,STL=** Stem tunnels length **,DH=** Dead heart **,IP=** Infested plant **, 1000SW=** thousand-seed weight(g)**, GY=** grain yield

,

Table (4.25): Phenotypic Correlation between morphological and damage parame

	PH	*SD*	*No.L/P*	*L A*	*DF*	*DM*	*YG*	*1000GW*	*PL*	*PW*	*PE*	*IP*	*DH*
PH	**1.000**												
SD	**0.199**	**1.000**											
No.L/P	**0.633***	**0.166**	**1.000**										
L A	**0.643***	**0.037**	**0.465***	**1.000**									
DF	**0.200**	**0.040**	**0.116**	**0.292**	**1.000**								
DM	**0.275**	**0.050**	**0.163**	**0.325**	**0.966***	**1.000**							
YG	**0.334**	**0.011**	**0.033**	**0.024**	**-0.146**	**-0.110**	**1.000**						
1000GW	**0.227**	**-0.045**	**0.109**	**0.169**	**-0.007**	**0.001**	**0.358***	**1.000**					
PL	**0.282**	**0.045**	**0.323**	**0.124**	**0.027**	**0.032**	**0.195**	**0.179**	**1.000**				
PW	**0.148**	**0.007**	**0.074**	**0.158**	**-0.090**	**-0.094**	**0.322**	**0.272**	**0.442***	**1.000**			
PE	**0.214**	**0.125**	**0.025**	**-0.032**	**-0.124**	**-0.096**	**0.301**	**0.062**	**-0.149**	**0.118**	**1.000**		
IP	**0.373***	**-0.111**	**0.288**	**0.328**	**0.170**	**0.201**	**-0.051**	**-0.053**	**-0.029**	**-0.059**	**0.067**	**1.000**	
DH	**0.181**	**-0.112**	**0.208**	**0.225**	**0.137**	**0.121**	**0.021**	**0.004**	**0.106**	**0.025**	**0.113**	**0.420***	**1.000**
ST	**0.408***	**0.011**	**0.354***	**0.449***	**-0.054**	**-0.019**	**0.048**	**0.025**	**-0.024**	**0.081**	**0.185**	**0.827***	**0.402***

*.** =Correlatio

PH =Plant height**,SD=** Stem diameter**,No.L/p =** Number of leaves /plant**,LA =** Leaf Area **, DF =** Days to 50% flowering **, DM =** Days length **,PW=** Panicle width **,STL=** Stem tunnels length **,DH=** Dead heart **,IP=** Infested plant **, 1000SW=** thousand-seed weight(g)**, GY=**

CHAPTER FIVE
DISCUSSION

Stem borers are one of the most destructive pests of the Sorghum crop. Its damage starts from third week of the emergence and continues till maturity. Three kinds of observations namely; percent leaf injury, dead hearts, stem tunneling were studied.

5.1 Field survey

The results of survey and identification indicated that, only two species of stem borers (*Chilo partellus* Swinhoe and *Sesamia cretica* Led.) were found to have wide distribution in Khartoum State at eight locations, with variable degrees of infestation. The sorghum crop in the study sites were infested by the both stem borers.The big rate of the infestation of the pest in all areas was found in Shambat.

5.2 Prevalence of *Chilo partellus* and *Sesamia cretica* in Khartoum State

Both *Chilo partellus*and Sesamia *cretica* damage were found to have a wide distribution in the Khartoum State on sorghum along the eastern, western, south and north. These results are in agreement with Schmutterer, (1969) who reported that both species of stem borers in Khartoum State. There was a significant difference between the number of *Chilo partellus* and *Sesamia cretica*. The highest infestation was recorded by *Chilo partellus*.These results are in agreement with those recorded by Starks, (1969); Young (1970); Seshu Reddy, (1998); Songa *et al*., (2001) and Sharma *et al.*, 2005) who found *Chilo partellus* (Swinhoe) as the predominant species, and the most important pest in East Africa and many countries of sub- Saharan Africa, while *Sesamia cretica* (Laderer) in MediterrareanEurope and the Middle East.

5.3 Observation on percent plant infested at 20,40 and 60 dasys:

5.3.1. Leaf Injury:

The present investigations on,"Screening of sorghum [*Sorghum bicolor* (L.) Moench] genotypes against stem borers (*Chilo partellus* Swinhoe and *Sesamia cretica* Led.) revealed that the less susceptible variety of sorghum against stem borers. The per cent plant infestation was ranged between 4.87 to 8.74% and 5.21 to 8.88% in Autumn and Winter respectively. There were significant differences among the Twenty- two genotypes. On the basis of leaf injury caused by stems borers. Similar findings were recorded by Jotwani *et al.,* (1972); Mahajan (1989); Singh *et al.,* (1991) Bhadviya (1995); Gour (1995); Sharma *et al.,* (2005); Dhillon *et al.,* (2006); Marulasiddesha *et al.* (2007); Kishore *et al.,* (2007) and Singh, *et al.*,(2011).

5.3.2 Dead hearts:

. There was significant difference among the Twenty- two genotypes in dead 'heart damage which ranged from 6.60 to 17.7% and 9.70 to 24.93% in both seasons Autumnand Winter respectively. On the basis of dead heart caused by stem borers, genotype G.1.1.4 was found less susceptible to dead hearts caused by stem borers followed by G.1.1.16, F-3 and Tabat. This was in accordance with the finding of Teli *et al.* (1983) who reported that 19.99 to 84.78% dead heart in different cultivars. Bhadviya (1995) recorded higher percentage (34.26 to 63.59) of dead heart damage by stem borers. Singh and Grewal (1997) recorded dead heart which ranged from 15 to 20 percent. The variation in per cent dead heart formation caused by stem borer might be due to different genotypes tested by different workers and variation in climatic condition of the tested station.These results are in agreement with those found bySharma *et al.*, (1983);Kishore (1991); Gour (1995); Jalauddin *et al.*,(1995); Patel *et al.* (1996)., Kushwaha (1996) and Elbadawi *et al.,* (1997).

5.3.3 Stem tunneling:

Data on stem tunneling were recorded at harvest. The observations on stem tunneling were significant among the Twenty- two genotypes. It ranged from 2.38 .to 5.32 % and 2.57 to 5.38 % in Autumn and Winter respectively. Minimum stem tunneling in genotype Tabat, G.1.1.4, which indicate that it is less susceptible to stem borer. Whereas, maximum and significantly higher stem tunneling 28.86(5.38%) - 28.28(5.32%) was recorded in F-6, F-8 which indicate higher susceptibilities to stem borer. These results are in agreement with Kishore (1991); Bhadviya (1995) and Gour (1995), while Singh *et al.,* (1991) concluded that the stem tunneling was more important parameter determining yield reduction rather than leaf injury.

5.4 Effecicct Stem Borer damage effect on growth characters:

Most of the growth characters were sensitive to infestation by stem borers, plant height, and leaf area, stem diameter, number of leaves, 50% days to flowering and the 95 %maturity. Moreover, infested or tolerance was highly significant reduced plant height in two seasons among all genotypes. Similar finding was shown by Kishore (1991) who found that effect of stem damage coincided with various growth stages such as 50 %flowering. and days to maturity. On the other hand, stem diameter, leaf area and number of leaves also were highly significant and decrease due to infestation). Generally, all of thesecharacters were highly tolerant in Winter and lower in Autumn.

5.5 Stem Borer damage effect on yield and yield components:

Damage of stem had highly significant effect on yield and yield component of all the twenty-two genotypes of sorghum used in this study. yield /plant showed high value (1.38t/ha,1.37) less susceptibility to stem borer. Whereas, small value (0.74t/ha, 0.76 t/ha) in higher susceptibility to stem borer in both seasons (Autumn-Winter) which found in genotype Arfdamk. Similar results showed by Singh *et al.,* (2011) who found that sorghum different in their tolerance to stem borers. Under natural infestation sorghum genotypes was deficit

reduced growth character and yield in grain sorghum, some were giving higher yield 1.37t/ha. 1000seed weight as the one of the yield components was affected by stem borers. Thereductionof thousand seed weight due to stem borers. Grain yield ton/ha was highly significantly affected by stem borer and high value were reported by G.1.1.4 in two seasons. This result matched the one reported byOdiyi (2007).

In this study G.1.1.4, F- 3.G.1.1.16, and F-5 scored high yield under natural infestation of stem borers (*Chilo partellus, Sesamia cretica)*.

This study identified sources of resistance to *C. partellus* based on leaf damage, dead heart formation, exit holes and stem tunneling. The reason for considering several parameters is due to the fact that resistance to *C. partellus* is a multi-mechanism, low-heritability quantitative trait, and thus, selecting for resistance based on a single parameter would not be effective (Singh *et al.,* 2011).

5.6 Phenotypic variability:

In this study and among the genotypes of sorghum the analysis of variance revealed significant differences ($P \leq 0.01$) for plant height, Stem diameter, number of leaf, day to 50% flowering, day to maturity, panicle length and grain yield on the other hand the ANOVA table revealed non-significant differences for plant height (cm), day to 50% flowering.

Genotype had significant effect on plant height at the two seasons (Table 2). F-5 genotype had a lesser plant height. This result confirmed the results of previous studies of Abd Rahaman, (1985);Abdalla, (1991); Ayub *et al.,* (1999); Yousef *et al.*, (2009) and Ayub *et al.,* (2010). While the earliest flowering maintainer genotype was Arfa gadamk (61 days), followed by F-7 (67.3days) and F-3 (67.3 days). Genotype had significant effect on number of days to 50% flowering and days to 95% physiological maturity. Arfa gadamk genotype was the earliest among all genotypes at the two seasons. For 1000 –grain weight genotype G.1.1.4, G.1.1.13 and F-12 were 45.55,45.45 and 44.5 g respectively. The results of grain yield showed that the relative resistance genotype G.1.1.4, F-3, and F-6

had the highest grain yield 1.38, 1.37 and 1.31ton/ha. Significant differences were found among genotypes in grain yield and yield related characters at the two seasons. These results are in agreement with those obtained by Mourad *et al.*, (1999) and Idris, (2006).

Average yield over all genotypes in the two seasons at Autumn was greater than Winter. This was mainly due to the higher number of grains per head at Autumn than Winter. Bell and Atkins (1967) and Doggett, (1970) reported that higher seed number generally is the most important yield component associated with increased in yield of sorghum. The reduction in the number of grains per panicle at Autumn was due to water stress at mid – season, caused by the relatively low amount of rains. Hutlquist, (1973) reported that water stress reduced significantly number of grains per panicle.

5.6.1 Phenotypic (δ^2ph) and genotypic (δ^2g) variability

Phenotypic variability estimated for twenty-two sorghum genotypes under natural infestation by stem borers variation can be attributed to phenotypic as well as genotypic. Similar conclusion was detected by others in different millet and different cereal crops under different environments as reported by Abuelgusim, (1989); Khalafalla, (1993)and Abraha *et al.,* (2015). Most of the characters, estimates for phenotypic variance were greater than their respective genotypic ones. This result indicates that large proportion of phenotypic variance for attributed was due to environmental effects. In general, the morphological characters had low genotypic variance than their respective phenotypic one. This results indicating that most differences among genotypes were mainly to environmental factors.

5.6.2 Phenotypic coefficient of variation (PCV) and genotypic coefficient of variation (GCV) and Heritability (H^2)

All characters showed wide range for individual character. Genotypic coefficient of variation (GCV) was maximum in grain yield (24.54, 28.45) for the two seasons and plant height (21.13 ,21.80) and it was not different with

phenotypic coefficient of variation (PCV) it was also showed maximum value in grain yield (28.87, 24.24) for the two seasons and plant height (23.29, 20.64) respectively. These results indicating that these traits were affected by environmental fluctuations. The high value of (GCV) and (PCV) suggested that there is possibility to environmental effect through direct selection for these traits. These results are similar to those reported by earlier scientist Amavati *et al.,* (2006); Abu *et al.,* (2010); Godbharle *et al.,* (2010); Ayelene, (2011); Mahajan, *et al.,*(2011) and Warked *et al.,*(2011)

High heritability in this study was showed among vegetative characters' plant height, leaf area, 50% flowering and number of leaves whereas it was less in thousand seed weight and grain yield (ton/ha). low heritability indicate that these characters are controlled by additive gene action and selection for these characters will be effective. High heritability for plant height have been revealed by Rao and Patil (1996). Similar results were observed by Bello *et al.,* (2001); Amavati *et al.,* (2006); Bello *et al.* (2007) and Abu *et al.,* (2010) who revealed that the low heritability estimate of grain yield is due to the direct and indirect multiplicative effects of yield components on grain yield.

5.7 Phenotypic correlation between different traits:

Estimates of phenotypic correlations between pairs of traits at the two Seasons were variable from one Season to another. This indicates that the strong inherent associations between different traits is different under the influence of environment and to the fact that phenotypic correlations are dependent on environmental conditions. Similar conclusions were also drawn by Falconer (1980) and Tesso *et al.,* (2011) to illustrate the change in the estimates of correlations among two Seasons, the positive close association between days to 50% flowering, number of leaves/plant, plant height with stem damage and among the genotypes. Similar results were reported by Soliman (1997) who found low correlation between results under natural and artificial infestation by *S. cretica*. Odiyi (2007) who studied the effect of infestation by *S. calamistis* on

grain yield found moderate to high correlations among most pairs of resistance expressing traits.

CONCLUSIONS

Based on the results obtained from this study, it could be concluded that:

 The present survey revealed. A wide distribution by both *Chilo partellus* and *Sesamia cretica* were found in the Khartoum State on sorghum along the eastern, western, southern and northern, with variable degrees of infestation.

 The highest infestation in all sites surveyed was seen in Shambat (60.34%) and the lowest infestation was noted in Soba (31.7%).

 Chilo partellus recorded higher infestation than *Sesamia cretica.* This may be due to the fact that Sorghumis preferred by *Chilo partellus,* while Zea maize is preferred by *Sesemia cretica*.

 The occurrence of a great genetic variability was detected betweensorghum genotypes for susceptibility and tolerance / resistance to stem borers infestation.

 Genotype G.1.1.4 was the most tolerant to stem borers infestation and is considered of useful and could be integrated in the national sorghum breeding program for developing sorghum hybrids with resistance to infestation by stem borers.

 Genotypes F-7, Tabat and G.1.1.16 were found to be less susceptible to stem borers infestation.

 Genotypes F-6 and F-15 was found highly susceptible to stem borers.

 Genotype F-6 scored the highest grain yield (1.31t/ha) despite of its obtaining a higher level of damage infestation percentage (69%) and higher percentage of dead hearts (4.99 %). therefore, it could be used in selection or hybridization for Sorghum genotypes characterization with high yield.

 Grain yield t/ha and its components were more sensitive to stem borer tolerance than other morphological characters.

 Reduction yield t/ha was mainly due to the reduction in yield /plant and thousand seed weight.

 Plant height, leaf area,1000 seed weight, and 50%, these characters recorded highest GCV, therefore it can be used as selection program.

 Grain yield t/ha had strong positive phenotypic and correlation with some of its components and some of morphological characters.

The results of phenotypic correlation obtained between different characters could be useful in grain sorghum breeding program.

RECOMMENDATIONS

Based on the results obtained from this study, it could be recommended that:

 Genotype G.1.1.4 was the most tolerant and is considered of useful and could be integrated in the national sorghum breeding program for developing sorghum hybrids with resistance to infestation by larvae of both *Chilo partellus and Sesamia cretica*.

 Genotype F-6 scored the highest grain yield under stem borers infestation and could be used in selection or hybridization for Sorghum genotypes characterized with high yield.

High phenotypic and genotypic variability was observed between the twenty-two sorghum genotypes; this variability could be of a great value in any genotype sorghum breeding programs.

Future research on the physiological, biochemical or genetic basis of the of the tolerance should be done.

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Appendix1: Meteorological data at Shambat Station during the growing seasons (Autumn and winter)2016/2017

Season	Month	Maximum Temperature (°C)	Minimum Temperature (°C)	Average temperature (°C)	Relative Humidity (%)	Total Rainfall (mm)
Autumn	July	37.9	25.6	32.5	47	72.5
	August	36.1	25.2	30.8	55	69.5
	September	39.2	25.2	32.8	63	23.0
	October	40.2	24.6	31.7	32	TR
	November	36.0	21.4	27.9	31	0.0
Winter	December	33.4	17.5	23.9	34	0.0
	January	31.9	16.5	24.2	28	0.0
	February	35.0	18.3	26.3	24	0.0
	March	38.4	19.4	28.2	17	0.0

TR = Trace Rain

Source: Shambat Meteorological Station.

Appendix 2: Mean average Stem borers infestation (%) on Sorghum at different sites in Khartoum State.

Sites	R1	R2	R3	Mean
Toti Island	36.98	38.37	39.81	38.38%
Gezira Islang	46.74	49.33	48.21	48.99%
Shambat	59.54	64.43	58.89	60.34%
Seleet Scheme	44.98	39.76	43.11	42.95%
El khadroo	47.43	44.21	49.22	46.14%
EL fakei Hashim	39.65	45.71	47.76	44.19%
Soba	29.33	32.9	33.11	31.7%
Tiba	36.98	38.37	39.81	33.83%

Appendix 3: Mean infested leaves *(%) attacked by Chilo partellus* at the different study sites

Count Date	R1	R2	R3	Mean
Toti Island	46.99	40.39	43.63	43.67
Gezira Islang	55.3	49.7	52.31	52.44
Shambat	69.32	65.98	60.47	65.26
Seleet Scheme	50.76	45.71	43.54	46.67
El khadroo	48.94	47.27	50.95	49.05
EL fakei Hashim	46.68	51.2	48.89	48.92
Soba	30.43	33.21	36.15	33.26
Tiba	32.74	40.94	29.82	34.50

Appendix 4: Mean infested leaves *(%) attacked bySesamia cretica* at the different study sites

Count Date	R1	R2	R3	Mean
Toti Island	26.95	36.29	36.00	33.08
Gezira Islang	38.00	48.97	44.11	43.69
Shambat	59.76	62.93	57.29	59.99
Seleet Scheme	39.21	33.69	42.78	38.56
El khadroo	45.93	41.27	47.49	44.90
EL fakei Hashim	32.65	40.21	46.63	39.83
Soba	28.44	32.62	30.07	30.38
Tiba	30.81	39.69	29.05	33.18

Appendix 5: Sorghum Layout Autumn Season 2016-17

Sowing date : 15/11/2016 ↑**N**

R1	**R2**	**R3**
1	5	16
5	3	10
12	9	2
6	14	5
9	1	4
2	6	16
3	12	14
8	11	12
14	2	3
4	10	6
10	16	15
13	8	8
16	7	13
7	13	7
15	15	11
11	4	9
18	17	22
17	22	18
19	18	20
22	19	17
21	20	21
20	21	19

Appendix6:Sorghum Layout Winter Season 2016-17

Sowing date: 17/7/2016↑**N**

R1	R2	R3
1	7	9
18	16	14
5	21	7
4	3	16
17	15	12
2	8	20
21	11	3
13	6	19
7	12	15
16	20	8
12	1	5
20	18	4
22	17	17
10	2	2
11	22	1
6	10	18
3	9	11
19	14	6
9	5	21
14	4	13
15	3	22
8	19	10

Appendix 7 :Mean of Infested plant, Dead hearts, Stem tunneling and Intensity of damage for 22 Sorghum genotypes attacked by *Chilo partellus* and *Sesamia cretica* at shambat in Autumn season 2016/2017

Genoypes	IP				ST				DH				ID			
	R1	R2	R3	Mean	R1	R2	R3	Mean	R1	R2	R3	Mean	R1	R2	R3	Mean
F -1	32.11	30.25	33.62	31.99	3.92	4.17	4.30	4.13	13	12	14.6	13.20	2.12	2.67	2.87	2.55
F -2	37.50	43.71	40.60	40.60	3.49	3.91	3.77	3.72	15	9.9	18.3	14.40	2.81	2.79	2.87	2.82
F -3	41.70	41.29	42.00	41.66	4.27	4.25	4.25	4.26	10	9	6.4	8.47	2.87	2.99	2.96	2.94
F -4	31.54	37.18	40.40	36.37	4.16	4.32	4.07	4.18	11.9	12	10.8	11.57	2.55	2.48	2.66	2.56
F -5	28.97	32.40	35.68	32.35	3.59	3.63	3.94	3.72	12	7.9	9.4	9.77	2.45	2.41	2.46	2.44
F -6	63.59	55.96	65.24	61.60	5.42	5.31	5.24	5.32	23	14	16.1	17.70	3.97	3.95	4.12	4.01
F -7	31.93	37.37	37.79	35.70	3.91	4.20	4.10	4.07	9.9	3	7.8	6.90	2.6	2.67	2.69	2.65
F -8	53.21	50.60	48.13	50.65	4.51	4.74	5.42	4.89	12	10	14.4	12.13	3.23	3.24	3.36	3.28
F -9	50.00	49.64	52.44	50.69	3.92	4.32	4.33	4.19	9	8.2	10.1	9.10	3.25	3.11	3.42	3.26
F -10	21.44	32.74	45.20	33.12	3.22	2.89	2.80	2.97	8.6	11	9.4	9.67	3.24	3.47	2.98	3.23
F -11	43.81	44.63	55.31	47.92	4.40	4.34	4.53	4.42	10.5	9.9	11.1	10.50	2.88	2.91	3.13	2.97
F -12	28.26	34.45	34.44	32.38	2.65	2.72	2.89	2.75	7.9	9.4	11.9	9.73	2.45	2.42	2.55	2.47
F-13	47.44	42.55	46.42	45.47	3.92	3.84	3.91	3.89	11.9	6.8	7.8	8.83	3.23	3.23	2.75	3.07
F -14	47.92	46.88	50.92	48.57	4.28	4.49	4.67	4.48	10	11.9	21.8	14.57	2.98	3.03	3.23	3.08
F -15	52.79	49.40	48.00	50.06	4.31	5.35	5.28	4.98	12	8.9	15.2	12.03	3.24	3.25	3.33	3.27
G.1.1.4	8.82	13.45	14.26	12.18	2.37	2.24	2.72	2.44	8	6	7.2	7.07	1.44	1.53	1.48	1.48
G.1.1.16	18.75	22.44	25.52	22.24	2.63	2.55	2.43	2.54	6.6	7	9	7.53	1.88	1.65	1.91	1.81
G.2.13.5	26.80	34.03	32.73	31.19	3.44	3.86	3.88	3.73	10.7	10.5	12.3	11.17	2.41	2.47	2.43	2.44
G.1.1.13	45.75	48.07	48.06	47.30	5.13	5.24	5.09	5.15	11	7	12.2	10.07	2.98	3.03	3.13	3.05
Tabat	11.18	14.62	17.70	14.50	2.32	2.46	2.36	2.38	0	2	19	7.00	2.44	2.35	2.46	2.42
W.Ahmad	41.42	46.08	40.98	42.83	2.99	3.13	3.08	3.07	8.8	7.7	8.5	8.33	2.81	2.92	2.9	2.88
Arfgadamk	35.92	37.20	35.73	36.28	4.36	4.22	4.31	4.30	7.9	5	6.9	6.60	2.8	2.81	2.87	2.83

IP= Infested plants, **DH=** Dead hearts **, ST =**Stem tunneling **and ID =** Intensity of damage

Appendix 8 :Mean of Infested plant, Dead hearts, Stem tunneling and Intensity of damage for 22 g
***Chilo partellus* and *Sesamia cretica* at shambat in Winter season 2016/201**

Genotypes	IP				ST				DH				
	R1	R2	R3	Mean	R1	R2	R3	Mean	R1	R2	R3	Mean	
F -1	38.40	39.79	38.24	38.81	4.23	4.40	4.29	4.31	14.10	13.90	14.90	14.30	2
F -2	45.31	42.04	50.30	45.88	3.82	4.09	3.99	3.97	18.60	18.00	18.00	18.20	2
F -3	47.00	41.19	41.79	43.32	4.36	4.45	4.24	4.35	21.70	15.60	22.00	19.77	2
F -4	36.98	38.10	45.70	40.26	4.01	4.25	4.25	4.17	22.20	15.20	21.80	19.73	2
F -5	32.87	30.78	46.59	36.75	3.64	3.70	3.96	3.77	13.50	16.90	15.00	15.13	2
F -6	59.74	55.78	62.66	59.39	5.41	5.32	5.30	5.34	22.50	22.00	30.30	24.93	3
F -7	35.02	35.26	38.19	36.16	4.25	4.31	4.22	4.26	16.90	9.90	17.40	14.73	2
F -8	58.31	53.36	57.43	56.37	5.32	5.45	5.36	5.38	11.30	20.70	18.80	16.93	3
F -9	54.31	49.29	47.56	50.39	4.19	4.18	4.27	4.21	17.00	6.00	19.40	14.13	3
F -10	32.24	33.18	37.41	34.28	2.97	3.00	3.01	3.00	18.50	8.90	22.70	16.70	2
F -11	57.59	54.23	60.02	57.28	4.53	4.46	4.50	4.50	19.50	16.00	17.00	17.50	2
F -12	33.60	41.67	39.44	38.23	2.82	2.86	3.01	2.89	18.10	19.20	20.40	19.23	2
F-13	52.86	47.19	52.44	50.83	4.06	3.99	4.01	4.02	18.00	12.00	13.00	14.33	3
F -14	60.24	51.79	54.06	55.37	4.51	4.65	4.43	4.53	19.00	16.00	22.50	19.17	3
F -15	69.48	59.48	64.03	64.33	5.33	5.36	5.39	5.36	20.00	22.40	21.90	21.43	3
G.1.1.4	11.74	16.67	16.96	15.12	2.51	2.75	2.46	2.57	19.10	0.00	10.00	9.70	1
G.1.1.16	24.11	25.49	18.36	22.65	2.77	2.61	2.61	2.67	10.70	0.00	21.70	10.80	2
G.2.13.5	31.47	45.10	37.78	38.12	3.98	3.83	4.00	3.94	16.00	22.00	21.00	19.67	2
G.1.1.13	46.65	52.05	50.51	49.73	5.09	5.19	5.25	5.18	25.00	6.60	29.00	20.20	2
Tabat	20.77	27.17	29.37	25.77	2.74	2.56	2.66	2.65	19.00	0.00	11.00	10.00	2
W.Ahmad	45.32	46.55	38.59	43.49	3.22	3.27	3.14	3.21	12.00	19.00	26.30	19.10	2
Arfgadamk	42.77	49.49	49.01	47.09	4.44	4.52	4.45	4.47	22.20	11.70	22.70	18.87	2

IP= Infested plants, **DH=** Dead hearts **, ST =**Stem tunneling **and ID =** Intensity of damage

Appendix 9: Mean sum of square values for different characters recorded on sorghun

In Autumn and Winter season 2016/2017

Source of Variance	DF	IP	DH	ID	Stem borer leaf injury		
					20 DAS	40DAS	60
Autumn Season							
Replication	2	92.719	1.41024	0.04303	1.15799	0.78550	0.
Genotypes	21	437.592	0.7099	0.84991	6.31895	3.90679	3.
Error	41	12.549	0.29765	0.01810	0.59112	0.16808	0.
Winter Season							
Replication	2	24.540	6.83579	0.02157	0.82499	0.04691	0.
Genotypes	21	452.399	1.20057	0.80379	3.93571	3.72649	3.
Error	41	16.734	0.71423	0.01493	0.4930	0.26259	0.

IP= Infested plants, **DH** = dead heart damage, **ID** = Intensity of damage,**LD (20DAS)** = leaf f damage in 20 days, **LD(40DAS)** = lea
LD(60DAS) = leaf f damage in 60 days, **ST** = stem tunnel damage,

Appendix 10: Mean of Some growth and yield traits of 22 genotypes at Shambat in Autumn

Genotype	PH				SD				NL/p				LA			
	R1	R2	R3	Mean	R1	R2	R3	Mean	R1	R2	R3	Mean	R1	R2	R3	
F -1	175.2	188	180	181.07	21.96	20.78	22.00	21.58	13.60	14.60	14.20	14.13	448	441	438	
F -2	152	140	155	149.00	16.08	19.20	16.40	17.23	14.60	13.40	12.00	13.33	433	467	424	
F -3	170	176.2	160	168.73	20.40	21.20	17.80	19.80	12.40	12.00	14.80	13.07	413	395	405	
F -4	149	158	158	155.00	18.40	15.20	16.20	16.60	14.40	12.00	15.40	13.93	534	539	510	
F -5	196	200	195	197.00	23.32	22.80	21.00	22.37	15.80	16.00	11.40	14.40	394	455	390	
F -6	196	195	190	193.67	20.78	20.40	19.20	20.13	13.20	12.00	12.60	12.60	434	428	488	
F -7	181	182	170	177.67	18.80	20.40	18.00	19.07	16.00	14.80	13.00	14.60	490	512	490	
F -8	186	188	180	184.67	20.90	19.00	18.92	19.61	14.00	12.60	13.40	13.33	504	481	474	
F -9	192	195	190	192.33	15.84	14.60	14.44	14.96	14.20	13.00	11.00	12.73	367	390	384	
F -10	160	161	164	161.67	19.40	18.23	17.00	18.21	18.00	15.00	11.00	14.67	436	437	448	
F -11	150	140	155	148.33	14.60	9.80	15.12	13.17	14.40	8.40	13.40	12.07	386	391	352	
F -12	179	182	179	180.00	20.06	17.40	16.00	17.82	14.40	12.40	14.00	13.60	458	458	460	
F-13	145	165	164	158.00	13.42	15.29	13.31	14.01	13.60	14.40	14.00	14.00	565	498	519	
F -14	135	145	135	138.33	18.18	16.80	16.18	17.05	14.80	14.00	14.40	14.40	421	417	424	
F -15	195	182	185	187.33	21.06	18.00	19.20	19.42	14.60	12.00	13.80	13.47	387	282	340	
G.1.1.4	105	125	133	121.00	20.20	21.20	19.21	20.20	14.80	15.00	16.20	15.33	466	458	483	
G.1.1.16	110	114	116	113.33	18.52	21.20	20.21	19.98	12.80	9.40	9.60	10.60	419	394	414	
G.2.13.5	109	125	120	118.00	13.21	14.29	14.87	14.12	12.00	9.20	8.40	9.87	449	461	456	
G.1.1.13	96	119	124	113.00	16.11	15.10	16.07	15.76	10.00	10.40	9.00	9.80	392	398	326	
Tabat	108	100	106	104.67	17.22	15.06	17.21	16.50	10.20	10.00	10.00	10.07	414	437	416	
W.Ahmad	130	125	130	128.33	17.08	17.00	18.01	17.36	10.00	9.00	10.00	9.67	281	317	497	
Arfgadamk	100	95	102	99.00	15.49	16.56	17.37	16.47	9.00	9.00	9.60	9.20	372	377	383	

PH = Plant height **, SD =** Stem diameter **NL =** Number leaves/plant **, LA =** Leaf Area **and DF =** Days to 50% floweri

Appendix 10 (Cont.)

Genotype	DM				PW				W.S				Yield/m^2			
	R1	**R2**	**R3**	**Mean**	**R1**	**R2**	**R3**	**Mean**	**R1**	**R2**	**R3**	**Mean**	**R1**	**R2**	**R3**	**Mean**
F -1	111	112	110	111.00	114	90	97	100.33	199	210	225	211.40	284	300	321	302.00
F -2	123	120	120	121.00	90	80	82	84.00	182	180	213	191.69	260	257	305	273.84
F -3	111	111	108	110.00	72	99	71	80.67	250	213	228	230.33	357	304	326	329.05
F -4	122	118	116	118.67	80	60	87	75.67	182	154	192	176.10	260	220	275	251.57
F -5	102	108	111	107.00	62	80	80	74.00	138	208	205	183.75	197	298	293	262.50
F -6	116	110	111	112.33	85	60	65	70.00	255	202	216	224.03	364	288	308	320.05
F -7	106	102	104	104.00	62	58	61	60.33	188	173	163	174.65	269	247	233	249.50
F -8	120	121	114	118.33	70	66	82	72.79	216	204	193	204.13	308	292	275	291.62
F -9	114	112	113	113.00	80	79	62	73.67	192	211	207	203.30	274	301	296	290.43
F -10	118	120	118	118.67	101	70	93	88.00	118	215	188	173.43	169	307	268	247.70
F -11	126	121	120	122.33	62	77	55	64.67	154	197	190	180.60	221	282	271	258.00
F -12	118	114	118	116.67	55	95	98	82.67	140	228	216	194.67	200	325	309	277.80
F-13	126	121	121	122.67	50	58	54	54.00	110	166	144	139.93	157	237	206	199.90
F -14	108	111	114	111.00	55	85	68	69.33	101	154	192	149.06	145	221	274	212.95
F -15	124	118	117	119.67	77	95	69	80.33	141	215	170	175.29	201	307	243	250.41
G.1.1.4	106	104	107	105.67	88	60	90	79.33	266	178	242	228.67	380	255	346	326.90
G.1.1.16	121	110	118	116.33	64	73	65	67.47	154	164	135	150.77	219	235	192	215.38
G.2.13.5	101	108	108	105.67	62	81	77	73.33	150	177	152	159.70	214	253	218	228.14
G.1.1.13	104	118	110	110.67	95	99	86	93.33	186	169	186	180.48	266	242	266	257.82
Tabat	110	111	108	109.67	77	82	63	74.00	164	205	174	181.03	235	293	248	258.62
W.Ahmad	111	106	106	107.67	54	70	73	65.67	181	169	149	166.27	259	241	213	237.52
Arfgadamk	104	102	102	102.67	70	72	69	70.33	125	117	140	127.23	178	167	200	181.70

DM = Days to 95 % maturity . **PW** = Plant dry weight ,**WS** = Weight of Seed/ , **yield/m^2** = Grain yield per m^2(g) and **YG** = Grain yield (ton/ha)

Appendix 10 (Cont.)

	TSW				PL				PW				
genotype	**R1**	**R2**	**R3**	**Mean**	**R1**	**R2**	**R3**	**Mean**	**R1**	**R2**	**R3**	**Mean**	**R1**
F -1	39.3	33.4	42.6	38.46	15	15	18	16.00	13	11	15	13.00	30
F -2	37.0	39.9	41.6	39.48	20	16	20	18.67	17	15	19	17.00	24
F -3	44.3	50.1	47.5	44.3	17	21	20	19.33	16	14	18	16.00	28
F -4	39.3	40.1	38.9	39.43	19	15	18	17.33	12	10	14	12.00	26
F -5	42.1	31.7	31.7	35.16	12	16	17	15.00	12	9	15	12.00	20
F -6	42.5	40.0	39.4	42.7	20	26	25	23.67	16	13	19	16.00	19
F -7	41.8	34.9	24.7	33.78	17	19	20	18.67	15	12	18	15.00	18
F -8	43.7	46.6	42.9	44.44	15	13	16	14.67	12	8	16	12.00	28
F -9	36.5	39.8	33.7	36.67	20	22	24	22.00	12	11	13	12.00	25
F -10	26.1	48.0	43.0	39.02	30	28	30	29.33	17	15	19	17.00	16
F -11	45.1	33.7	31.7	36.86	17	15	18	16.67	15	12	18	15.00	24
F -12	45.6	46.0	42.7	44.76	21	17	20	19.33	14	12	16	14.00	22
F-13	32.3	31.1	29.9	31.11	20	20	21	20.33	10	11	12	11.00	19
F -14	46.6	37.0	39.4	41.00	15	19	18	17.33	10	10	13	11.00	24
F -15	43.5	43.7	42.0	43.09	24	16	20	20.00	12	13	11	12.00	26
G.1.1.4	46.1	44.5	47.9	46.16	20	24	23	22.33	17	15	19	17.00	22
G.1.1.16	34.0	30.8	29.0	31.25	18	14	18	16.67	14	12	13	13.00	21
G.2.13.5	49.3	40.1	40.1	43.17	12	16	16	14.67	10	14	12	12.00	25
G.1.1.13	47.7	46.3	44.0	46.01	22	20	22	21.33	15	19	17	17.00	19
Tabat	42.1	45.1	45.1	44.08	15	18	17	16.67	11	10	12	11.00	25
W.Ahmad	30.7	37.0	25.8	31.19	19	15	18	17.33	9	8	10	9.00	18
Arfgadamk	24.9	22.9	24.0	23.92	21	17	20	19.33	11	7	9	9.00	23

TSW=Thousand seed weight **(g); PL =** Panicle length(cm)**, PW=** Panicle weight (g) **and PE=** Panicle ex

Appendix 11: Mean of Some growth and yield traits of 22genotypes at Shambat in Winter s

Genotype	PH				SD				NL/p				LA			
	R1	R2	R3	Mean	R1	R2	R3	Mean	R1	R2	R3	Mean	R1	R2	R3	Mean
F -1	164	204	182	183.33	13.84	14.32	13.08	13.75	11.4	14	11.8	12.40	385	379	394	386.0
F -2	148	192	189	176.33	14.43	14.40	15.86	14.90	12.8	12	11.4	12.07	393	412	383	396.0
F -3	165	206	184	185.00	18.29	15.89	13.06	15.75	11.1	14	10.8	11.97	385	391	399	391.6
F -4	150	216	206	190.67	14.34	17.64	16.90	16.29	10.2	13	12	11.73	512	513	536	520.1
F -5	194	184	190	189.33	14.56	16.33	18.54	16.48	13.2	17	11.2	13.80	386	405	431	407.3
F -6	198	170	204	190.67	15.04	13.48	17.19	15.23	12.4	12	12	12.13	437	422	499	452.6
F -7	185	178	169	177.33	14.05	14.32	16.60	14.99	10.8	12	12	11.60	494	490	474	485.9
F -8	181	185	192	186.00	16.00	16.19	15.43	15.87	12.2	11.2	12	11.80	499	490	465	484.6
F -9	204	193	180	192.33	14.10	18.52	13.95	15.52	13.2	13.2	12.4	12.93	470	419	389	426.0
F -10	158	160	175	164.33	17.32	15.57	16.35	16.41	16.4	10	10.8	12.40	427	433	413	424.2
F -11	145	145	160	150.00	13.82	11.77	14.86	13.48	10.4	10.4	11	10.60	363	371	397	377.1
F -12	190	175	182	182.33	15.32	15.60	15.03	15.31	11.6	11	10.6	11.07	461	447	435	447.7
F-13	153	158	174	161.67	17.65	18.22	19.22	18.36	12	11	12.2	11.73	509	488	511	502.5
F -14	140	138	140	139.33	13.58	15.93	14.98	14.83	12.3	15	12	13.10	432	397	410	413.0
F -15	201	190	195	195.33	12.34	14.77	15.12	14.08	11.3	10	10	10.43	383	348	357	362.8
G.1.1.4	121	130	122	124.33	18.84	19.89	18.35	19.03	13	13	14	13.33	452	461	465	459.2
G.1.1.16	112	120	114	115.33	18.91	16.23	18.44	17.86	10	9.4	9.2	9.53	381	356	375	370.5
G.2.13.5	119	120	118	119.00	11.88	12.98	15.31	13.39	10	11.8	11.2	11.00	427	474	467	455.8
G.1.1.13	110	121	122	117.67	15.20	16.26	16.58	16.01	11	12.2	8.8	10.67	420	426	398	414.6
Tabat	98	108	96	100.67	16.97	13.04	16.43	15.48	9	7.8	9	8.60	282	285	275	280.7
W.Ahmad	101	96	98	98.33	11.93	15.52	15.37	14.27	9	8.6	10.6	9.40	228	206	246	226.5
Arfgadamk	90	108	110	102.67	14.48	16.36	14.28	15.04	9.6	9	9.6	9.40	329	368	345	347.2

PH = Plant height **, SD =** Stem diameter **NL =** Number leaves/plant **, LA =** Leaf Area **and DF =** Days to 50% floweri

Appendix 11 (Cont.)

Genotype	DM				GM				WS				
	R1	R2	R3	Mean	R1	R2	R3	Mean	R1	R2	R3	Mean	I
F -1	110	108	104	107.33	104	93	89	95.54	187	205	220	204.07	1
F -2	122	126	119	122.33	81	97	80	85.75	177	175	208	186.69	1
F -3	101	102	104	102.33	62	113	57	77.31	248	208	223	226.33	1
F -4	122	122	123	122.33	86	54	100	79.82	181	149	187	172.46	1
F -5	104	111	114	109.67	65	85	77	75.30	136	203	200	179.88	0
F -6	116	108	116	113.33	58	55	77	63.06	235	197	211	214.03	1
F -7	108	104	110	107.33	59	57	54	56.54	184	168	158	169.92	1
F -8	111	111	108	110.00	71	66	88	75.21	211	199	188	199.13	1
F -9	111	108	112	110.33	76	76	54	68.75	187	206	202	198.30	1
F -10	118	122	116	118.67	100	69	96	88.64	113	210	183	168.43	0
F -11	126	127	122	125.00	58	61	60	59.54	149	192	185	175.60	0
F -12	114	112	111	112.33	52	93	90	78.33	135	223	211	189.67	0
F-13	121	125	120	122.00	43	53	48	48.11	105	161	139	134.93	0
F -14	114	110	116	113.33	57	80	62	66.66	96	149	187	144.06	0
F -15	124	120	123	122.33	87	95	61	81.15	136	210	165	170.29	0
G.1.1.4	106	110	112	109.33	86	52	87	75.00	265	173	237	225.00	1
G.1.1.16	121	118	121	120.00	50	73	58	60.28	149	159	130	145.77	0
G.2.13.5	112	114	102	109.33	60	84	74	72.75	145	172	147	154.70	0
G.1.1.13	106	102	108	105.33	93	96	82	90.50	181	164	181	175.48	1
Tabat	106	101	111	106.00	78	76	64	72.56	159	200	169	176.03	0
W.Ahmad	108	108	113	109.67	43	68	74	61.91	176	164	144	161.27	1
Arfgadamk	98	96	99	97.67	67	72	61	66.71	120	112	142	124.40	0

DM = Days to 50% maturity **, GM=** Grain massr **WS=** Weight of seeds **and GY** = Grain yield/g

Appendix 11 (Cont.)

Genotype	TSW				PL				PW				
	R1	R2	R3	Mean	R1	R2	R3	Mean	R1	R2	R3	Mean	
F -1	37.1	32.7	38.6	36.14	19	17	18	18.00	9	11	10	10.00	
F -2	36.1	39.0	40.7	38.61	17	15	16	16.00	10	9	8	9.00	
F -3	46.5	47.1	42.0	45.19	18	20	19	19.00	13	15	14	14.00	
F -4	39.3	39.0	38.0	38.77	16	17	18	17.00	11	10	9	10.00	
F -5	41.9	31.0	31.0	34.63	24	22	20	22.00	12	13	11	12.00	
F -6	44.1	41.4	41.0	42.17	25	24	23	24.00	16	17	15	16.00	
F -7	41.0	34.0	24.0	33.01	20	18	16	18.00	14	13	15	14.00	
F -8	44.1	41.4	41.0	42.17	14	16	12	14.00	8	10	12	10.00	
F -9	48.0	39.1	39.0	35.60	23	19	24	22.00	12	11	13	12.00	
F -10	44.1	41.4	41.0	43.17	27	26	25	26.00	11	10	12	11.00	
F -11	43.9	33.0	31.0	36.97	15	19	17	17.00	12	13	11	12.00	
F -12	44.7	43.7	47.0	44.81	19	18	20	19.00	13	13	16	14.00	
F-13	31.0	30.3	29.0	31.10	21	19	20	20.00	10	12	11	11.00	
F -14	44.7	36.0	38.5	39.74	17	18	16	17.00	11	9	10	10.00	
F -15	42.2	42.9	41.0	42.03	19	20	21	20.00	12	11	13	12.00	
G.1.1.4	44.7	43.7	47.0	45.14	22	21	23	22.00	14	13	15	14.00	
G.1.1.16	33.0	30.0	28.0	30.33	15	15	18	16.00	13	14	12	13.00	
G.2.13.5	48.0	39.1	39.0	42.03	13	14	15	14.00	9	11	10	10.00	
G.1.1.13	37.1	32.7	38.6	44.92	21	20	22	21.00	15	17	16	16.00	
Tabat	41.0	44.2	44.0	43.07	17	16	15	16.00	10	11	12	11.00	
W.Ahmad	30.0	36.1	25.0	30.37	16	17	18	17.00	9	8	10	9.00	
Arfgadamk	24.0	22.0	23.7	23.23	17	18	16	17.00	8	8	11	9.00	

TSW=Thousand seed weight **(g); PL =** Panicle length(cm)**, PW=** Panicle weight (g) **and PE=** Panicle ex

Appendix 12: Mean Squares of some morphological and yield component characters of 22 genoty in Shambat at Autumn season2016- 17

Source of Variation	DF	Parameters				
		PH	STM	NO.L	LA	DF
Replication	2	89.40	3.5293	11.0406	90.97	10.015
Genotypes	21	3047.20**	18.6153**	11.0607**	8071.79**	91.4199
Error	41	48.28	1.7529	2.0673	1130.68	9.8723
C.V		4.53	7.44	11.34	7.81	4.25

Appendix 12 (Cont.)

Source of Variation	DF	Parameters			
		PL	PE	PW	1000GW
Replication	2	14.1061	4.2273	0.1061	33.072
Genotypes	21	34.3761	11.8016	10.4964	105.602**
Error	41	0.5346	11.6241	1.3124	19.829
C.V		3.81	15.15	9.09	11.48

(PH) = Plant height in cm, **(SD)**-=stem diameter, **(No.L)** = Number of leaves per plant, **(LA)** = Leaf Area, **(DF)** = Days to 50% flowering, **(DM** Panicle length in cm, **(PW**)= Panicle width in cm, **(PE)** = Panicle Exsetion in cm,(**1000GW)** = Thousand grain weight in gm, and **(YG to/ha)**= Y
****** = significant at the 0.01 level of probability
***** = Significant at the 0.05level of probability

Appendix 13: Mean Squares of some morphological and yield component characters of 22 g
grown in Shambat at Winter season2016- 17

Source of Variation	DF	Parameters				
		PH	STM	NO.L	LA	DF
Replication	2	451.14	3.72460	1.96955	94.3	29.742
Genotypes	21	3652.78**	6.50233**	5.73363**	14377.4**	139.865*
Error	41	164.80	2.25709	1.7908	379.7	8.631
C.V		8.21	9.65	11.70	4.75	3.98

Appendix 13 (Cont.)

Source of Variation	DF	Parameters			
		PL	PE	PW	1000GW
Replication	2	0.4091	4.1970	2.2273	61.064
Genotypes	21	29.1948	30.9380	13.9805	110.117**
Error	41	1.9805	2.4033	1.2749	12.013
C.V		7.51	6.78	9.59	9.05

(PH) = Plant height in cm, **(SD)**-=stem diameter, **(No.L)** = Number of leaves per plant, **(LA)** = Leaf Area, **(DF)** = Days to 50% flowering, **(DM** Panicle length in cm, **(PW**)= Panicle width in cm, **(PE)** = Panicle Exsetion in cm,(**1000GW)** = Thousand grain weight in gm, and **(YG to/ha)**= Y
****** = significant at the 0.01 level of probability
***** = Significant at the 0.05level of probability